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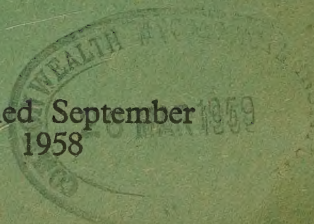
COFFEE RESEARCH STATION, RUIRU

AND

COFFEE RESEARCH SERVICES
KENYA

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Published September
1958



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WHITE RESEARCH STATION, NAIROBI

1951

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REPORT

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PREFACE

Since the Coffee Team was formed in 1937 the results of research have been reported annually in a section of the Annual Report of the Department of Agriculture. It has been found in practice that when these are incorporated into a larger report of wide scope the full details of coffee investigations have not been readily accessible to the coffee planter in Kenya nor to other interested parties. Consequently on the advice of the Coffee Research Advisory Committee, the Coffee Board of Kenya has asked that a comprehensive annual report be issued as a separate edition and has provided funds to allow this request to be implemented. We are pleased to be able to accede to this request, which will allow a fuller presentation and description of results of all investigation projects and will permit mention of progress in the full range of our activities.

This, the first edition produced as a separate publication, aims to present in full detail the investigations in hand during 1956-57, preceded by a summary of past work and results.

The general purpose of this compilation is to describe the research being undertaken in detail; subsequent editions will report progress only without basic details, except in respect of new trials. Thus it is possible to describe the aim and details of an experiment once only and to report progress in chronological sequence in subsequent editions. Unnecessary repetition of basic details can be avoided by this means.

STAFF OF COFFEE RESEARCH SERVICES: MARCH, 1957

Officer-in-Charge:

P. A. JONES, B.A. AGRIC. (CANTAB.), Agricultural Officer

Agricultural Officer (Investigations):

J. A. N. WALLIS, B.A. AGRIC. (CANTAB.), D.T.A. (TRIN.)

Entomologist:

D. J. McCRAE, B.SC. HONS. AGRIC. ZOO. (EDIN.)

Plant Pathologist/Physiologist:

R. W. RAYNER, B.A. HONS. (CANTAB.), A.I.C.T.A.

Agricultural Chemist:

J. B. D. ROBINSON, B.SC. HONS. AGRIC. CHEM. (READING), F.R.I.C.

Agricultural Officer (African Areas):

B. F. HANGER, B.SC. (READING), D.T.A. (TRIN.)

Laboratory Technologists:

MRS. W. NICHOLLS, B.SC. (WALES) (Plant Pathology/Physiology)

K. A. HARRISON (Entomology)

VACANT (Chemistry)

Senior Assistant Agricultural Officer:

E. COTTINGTON (Advisory Officer)

Assistant Agricultural Officers:

S. D. GOODWIN

P. THOMS, DIP. AGRIC. (N.Z.)

H. H. J. DE VINK, DIP. AGRIC. (DEV.)

I. R. WALLACE, N.D.A., C.D.A.

J. S. GRANT, DIP. AGRIC. (EGERTON)

M. H. UITERDYK, DIP. HORT. (BOSK.)

Laboratory Technologist (Trainee):

MISS G. S. HARCOMBE

Office Superintendent:

MRS. T. JANES

Stenographer/Secretary:

MRS. V. F. M. ROYDS



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INTRODUCTION

The weather and conditions affecting the trees and crop, in the East of Rift districts particularly, were similar in many respects to those in 1955. Exceptional rains in January and February allowed a rapid recovery from the effects of crop strain and the defoliation due to Leaf Rust, but engendered another Rust epidemic of even greater severity. Fortunately widespread early flowerings brought crops to maturity sooner than normal and generally most of the strain on the trees had occurred before heavy leaf-fall started. Nevertheless, heavy Leaf Rust infection and widespread attacks of Leafminers were responsible for serious defoliation during the second half of the year. The prolonged dry weather which followed poor rainfall in May lowered the quality of the crop, especially the latter half of the harvest. From September to the end of the year rainfall was light but well distributed.

Rainfall at the Department's Coffee Stations during 1956 (inches)

1956	A	B	C	D
January . . .	3.90	5.16	6.14	3.42
February . . .	3.50	2.56	1.81	3.21
March . . .	4.83	3.04	4.91	2.94
April . . .	8.98	6.32	11.98	4.84
May . . .	3.20	2.53	2.94	5.93
June . . .	0.88	0.64	0.04	1.97
July . . .	0.54	0.73	0.14	5.17
August . . .	1.01	0.42	0.18	8.51
September . . .	1.33	0.66	1.00	4.17
October . . .	2.62	1.21	1.44	4.29
November . . .	5.57	3.87	8.32	0.62
December . . .	0.61	0.92	1.75	5.57
Total inches .	36.97	28.46	39.81	50.64
Total days .	128	100	90	169

A= Coffee Research Station, Ruiru.

B= Scott Agricultural Laboratories.

C= North Kitito Estate, Makuyu.

D= Kitale Experimental Station.

Among the number of staff changes during the year there were in particular the transfer on promotion to Chief Research Officer of Mr. A. R. Melville, who was succeeded by Mr. P. A. Jones as Officer-in-Charge in February. Mr. J. A. N. Wallis assumed duty as Agricultural Officer (Investigations) in May.

A special Coffee Berry Disease Research Unit was formed at the end of 1955 to undertake the investigation of all relevant aspects of the disease in the Colony. The unit is under the direction of Dr. F. J. Nutman whose report on the year's work appears elsewhere in this volume.

In the field of processing, research investigations into the problems of artificial drying of parchment coffee were continued as a special project by the East African Industrial Research Organization and were conducted by Mr. J. F. McCloy, Senior Scientific Officer, who was appointed to succeed Mr. D. A. B. Llewelyn in April. In June Mr. J. S. Grant, Assistant Agricultural Officer, was seconded to assist with field studies on estates. Although a final answer is not yet in sight some useful

conclusions to relevant aspects of this intractable problem were achieved during the year. Studies were designed to assess the effect on coffee quality of a range of drying temperatures applied at various stages in the drying cycle and the relation of sun-drying to the production of good quality coffee. Full reports of these studies were issued periodically by the East African Industrial Research Organization.

In agronomic research one of the main developments was the inception of a long-term irrigation trial designed to study the important questions arising from the rapidly increasing practice of irrigation in the drier coffee-growing areas. The design of the trial, described in the report of the Agricultural Officer (Investigations), was reached after much collaboration with Dr. H. C. Pereira, E.A.A.F.R.O. Papers describing fully the approach to the problem and the layout of the trial were published.*

Field investigations of the effects of grass mulches, nitrogenous fertilizers and cattle manure have continued, and although the conclusions previously obtained have been largely endorsed some interesting new indications of the interaction of these soil treatments are emerging.

Messrs. Rayner and Wallis have continued research on anti-leaf-fall spraying in trials at Ruiru, Kitale, Solai and Makuyu. The relative value of high-, medium- and low-volume sprays is now under scrutiny in machine spray trials at Ruiru. At other sites time studies have shown that "tonic" applications in May control leaf-fall more effectively than at other times and lead to greater crop increments. Various other and less important aspects of the practice were examined in the course of the year.

Conditions predisposing to another Leaf Rust epidemic underlined the importance of new lines of research in field and laboratory, wherein efforts to elucidate the factors affecting infection and their relation to control by fungicide spraying have yielded results of profound significance, necessitating a revised approach to spraying technique. Varietal resistance is assuming importance of unexpected magnitude as development of coffee growing in African areas accelerates. Consequently, the work of routine testing of Rust collections was started to determine differential host reaction and the distribution of physiologic races of the Rust throughout the Colony.

Rust-resistant varieties from other territories must necessarily be subjected to field tests before their value can be established. For this purpose a series of Rust exposure trials was laid down in the several climatic zones of the Colony to reveal the differential reaction of imported and local strains and to confirm the results of laboratory studies wherein the distribution of Rust races is determined.

The Agricultural Chemist's main line of research continued to be the study of soil nitrogen and nitrogen nutrition of coffee. From this vast and complex problem some useful conclusions were extracted, especially those arising from laboratory incubation studies. Preliminary examination of magnesium nutrition of coffee showed that the subject warranted intensive investigation. The studies described in detail later in this report constitute the record of how the magnesium deficiency condition has been defined. Although a practical remedy is apparently no problem the full implications have not yet been determined.

The most important developments in entomology have been the work of assessing the value of some new insecticides in the control of Antestia and Leafminers. Serious outbreaks of the latter pest caused much concern to growers, but fortunately experiments indicated that a fully effective control was in sight. Mr. McCrae devoted much attention to studying Tip Borers; although a clearer understanding of the biology of both species was attained, unfortunately in respect of *Eucosma nereidopa*, the more noxious species, no suitable control could be found.

* Included in the list of publications at the end of the Irrigation Trial section.

In African districts coffee growing developed at a rapid pace during the year. In addition to surveys in zones of prospective development the Coffee Team continued to serve as technical advisers to departmental field officers in African areas. The post of liaison officer between the research station and the African coffee areas was filled by the appointment of Mr. B. F. Hanger, Agricultural Officer, in August, who underwent a period of study at the research station before commencing his liaison duties towards the close of the year.

Plans for a sub-station at Kisii were brought into effect when the initial work of surveying, fencing, bush-clearing, etc., was commenced in February. This and a second station on Mount Kenya will play a vital part in the development of coffee in the two provinces; outstanding cultural problems can only be solved satisfactorily by field studies under their particular climatic conditions.

Satisfactory progress has been recorded in the variety trial programme; several new areas were planted with exploratory trials and a series of Rust exposure trials was started. The latter are designed to reveal the differential reaction of resistant strains and to determine the distribution of Rust races throughout the Colony.

THE COFFEE RESEARCH STATION AND COFFEE SERVICES

FUNCTION OF THE COFFEE SERVICES IN KENYA

Our aim is the extension and improvement of coffee culture in all parts of the Colony. This involves research in the laboratories and field experiments on Jacaranda Estate and at sub-stations and plots at Kitale, Solai, Makuyu, Upper Kiambu and the Scott Agricultural Laboratories, Nairobi.

Although results obtained at this station are, of course, immediately applicable in a large and very productive area East of the Rift Valley, it is important to realize that, as conditions diverge from those obtaining at Ruiru, this ceases to be so and that while a few of our Jacaranda results are directly applicable to all parts of the Colony, the great majority require to be tested throughout the range of conditions obtaining in the Colony's coffee areas before they can be introduced into local practice. It is for this reason that the sub-stations and plots mentioned above are maintained.

In connection with coffee growing by Africans in Kenya, we have been assisting the Provincial Agricultural Officers with general advice on various aspects of coffee culture and in the establishment of variety trials in all African areas as an essential preliminary to extension of coffee growing by Africans.

In general, extension work is carried out to disseminate the knowledge in our possession by means of visits to growers, articles in the Press (chiefly in the Monthly Bulletin of the Coffee Board), and the activities of the demonstration farm (Rukera) which gives the Coffee Services staff an opportunity to weld proved practices developed on the research station into a balanced farming system well suited to its environment and to exhibit the results.

The closest possible liaison is maintained with the Officers of the District Headquarters of the Soil Conservation Service both in research and extension work.

Official contact with the coffee industry is maintained through the Coffee Research Committee. Under the chairmanship of the Chief Research Officer, six planter members and members of the research station staff meet quarterly to discuss research and extension matters.

Finally, while the main accent is definitely on coffee, every opportunity is taken to carry out work of wider scope. Cattle play an important part in our activities as do also the improvement and better management of grazing. Observations are being carried out with a view to finding improved pasture, mulch and fodder species.

THE COFFEE RESEARCH STATION

Jacaranda Estate—General Description

When Jacaranda Estate was purchased in May, 1944, the total area of 329 acres included 165 acres of established coffee. The initial step in the programme of improvement of the estate and its preparation for experimental work was the uprooting of coffee on the poorer land and planting such land with Napier grass. A small area of better land similarly treated was destined to return to coffee after a period of regeneration under this grass crop. The remaining 100 acres of coffee were stumped and regenerated on both the single- and multiple-stem systems of pruning. Since then the main method of soil and root regeneration has been through the use of alternate row mulches in all coffee plots (except where the nature of the experiments contained therein do not permit this treatment). Despite prolonged periods of drought these steps have led to crops of improved quantity and quality.

The best land on the estate is devoted to coffee experiments, which require an even level of fertility and growing conditions. The most suitable land of this type on the estate extends from Plot 1 to the boundary on the north-west side. The adjacent areas have been planted with Napier grass to provide mulch for coffee, bedding and fodder for cattle. Outside these areas there is little land which is not too steep to plough. Nevertheless five areas of approximately five acres each were found and on these a scheme for pasture improvement was commenced in 1948.

Briefly the scheme operated as follows: After bush clearing and fencing the paddocks remained as rough grazing until broken (one paddock per year) for the arable course of the ley rotation. Three crops of yellow maize were taken for ensilage, the last being undersown with Nzoia Rhodes grass and Hunter River lucerne. When fully established, leys were grazed in rotation and mown for hay.

The original scheme has been modified as indicated by experience and it is now customary to grow Canadian Wonder beans as the first crop of the arable break. Experiments demonstrated that dressings of Double Superphosphate (drilled at 1 cwt./acre) and Sulphate of Ammonia (broadcast at 1 cwt./acre) were essential for satisfactory crops of maize.

The addition of 52 acres of land from Rukera Estate, consisting of that portion which lies to the north of the main ridge road, provided three more paddocks and allowed the ley period to be extended to six or seven years. A further 15 acres, which was used as a temporary ley, has been broken and replanted to coffee during the last two years. The remainder of the flatter land at the top of the estate is scheduled for replanting in due course.

Land too steep for the plough has been cleared of bush and fenced. Under a policy of rotational grazing these permanent pastures have been improved in composition and production. Land too steep for clearing near the Komassai River has been left in bush and is thus well protected.

Acreage Summary

The total area of Jacaranda Estate is 381 acres and this is now used as follows :—

Coffee:

Regenerated multiple stem	37 acres
Regenerated single stem	30 „
New bearing trees	15 „
Immature trees	17 „
	—
	99 acres
	—
Napier grass plots	33 acres
Napier grass areas (regenerating under arable)	14 „
Ley rotation paddocks	20 „
Remainder	205 „

The considerable acreage which remains comprises rough grazing paddocks, steep slopes in bush or trees, vleis, gum plantations, buildings and roads, nurseries, camps, etc.

Climate and Soil

The altitude is approximately 5,400 feet above sea level. The distribution of rainfall follows the monsoon pattern, with two wet seasons per year which are locally referred to as Long Rains (March to mid-June) and Short Rains (mid-October to mid-December). In the intervening dry periods drought conditions are usually severe.

Meteorological records have only been taken since 1945.

<i>Year</i>	<i>Total Rainfall</i>	<i>Range of daily Max. and Min. Shade Temperatures</i>
1945	36.50"	45°F. to 92°F.
1946	40.34"	47°F. to 88°F.
1947	52.42"	44°F. to 86°F.
1948	31.44"	46°F. to 86°F.
1949	25.51"	43°F. to 87°F.
1950	26.20"	44°F. to 86°F.
1951	54.05"	45°F. to 88°F.
1952	39.40"	44°F. to 89°F.
1953	27.86"	43°F. to 87°F.
1954	36.21"	46°F. to 88°F.
1955	31.39"	45°F. to 86°F.
1956	36.97"	44°F. to 86°F.
Mean	36.52"	45°F. to 87°F.

The main soil type present, and that on which the coffee is grown, is the Kikuyu red and to a lesser extent the dark red loam soil. It is a deep, porous and naturally well drained lateritic soil derived from a volcanic parent material (*Tertiary trachytic* lava), by weathering *in situ*. It has a fairly high plant food (base) holding capacity and very good physical properties. It is naturally well drained with a high pore space, i.e. 60-65% apparent soil volume, and, although it contains a high percentage of clay, from 60-80% by analysis, the field texture is that of a friable loam.

The highly porous surface soil has a good natural crumb structure and it is resistant to erosion. The soil depth may exceed 20 feet on the main ridges and will fall to two feet or less on the flanks immediately above the river valleys which bound the two estates.

At the end of this report is appended a copy of the soil survey map, as prepared by Mr. G. H. Gethin-Jones, Soil Survey Department, East African Agriculture and Forestry Research Organization. The soils have been classified and mapped into seven Soil Series with additional phases to allow for seasonal impeded drainage (areas of topographical depression), steepness of slope, shallowness of soil and a combination of the latter two factors. It will be noted that almost the entire coffee acreage is sited on the Kikuyu red or dark red loam soil types.

Jacaranda Estate—Development, 1956-57

During the year under review funds for capital development, comprising the residual balance from the previous year, were expended mainly in completing and extending existing facilities, viz. :—

A ring fence was erected around the main crop and sample drying ground, a concrete barbecue for drying mbuni and pulp was constructed near the factory. In order to comply more literally with section 74 of the Water Rules a pulp separator and stone hopper were installed, effluent channels were realigned to new seepage pits sited closer to the factory.

A social hall and shop was built for the use of African staff.

The filtration plant installed on Jacaranda ten years ago was designed to supply water to houses and laboratories at a rate which has become increasingly below the consumption level as the station expanded. In November a borehole was drilled at the top end of the estate; with a tested yield of 6,000 gallons per hour of good quality water it represents a most valuable asset which, when equipped, will replace the obsolete and inadequate plant used hitherto.

Jacaranda Estate Crop 1956-57

Rainfall—1.1.56 to 31.12.56 (inches)	.	.	.	.	36.97
Acreage in production	.	.	.	.	85.49
Clean coffee (tons)	.	.	.	.	18.72
Mbuni (lb.)	.	.	.	.	19,950

Classifications	lb.	Percentage
Class 2	7,273	17.34
„ 3	10,793	25.74
„ 4	10,092	24.07
„ 5	3,110	7.42
„ 6	3,364	8.02
„ 7	1,059	2.52
„ 8	3,818	9.10
„ 9	1,270	3.03
„ 10	148	0.35
„ 11	766	1.83
„ 13	244	0.58
	41,937	100%

The average basic scale price of the crop was 104.2 cents per pound. In addition to the above, samples amounting to one-tenth of the crop from 26.3 acres were extracted for calculating the yields from field experiments.

The Cattle on Jacaranda Estate

The herd of Zebu cattle which was transferred to Jacaranda from the Scott Laboratories in 1946 was mostly of Boran origin, consisting of Kenya Boran and Somalia Boran (Serenle) animals.

Apart from the necessity to produce manure for the estate the original aim was genetic improvement by selection of a dairy-type animal for high milk yield. The breeding policy proved too ambitious for the small size of herd and the level of supervision which could be afforded. Consequently the decision to change over to a beef herd was made in 1955, with the aim of undertaking simple studies of beef production as it affects coffee estates. Twelve beef-type heifers were selected for artificial insemination by a Hereford bull, while the remainder of the herd was sold. Proceeds from the sale will be used to purchase pure-bred beef Boran heifers and a registered Boran bull. These will form the nucleus of the new herd from which observations on quality, growth, maturity, finishing time, etc., may be made.

Mulches and Pasture Improvement

A number of new species was acquired for observation and testing in the grass and legume plots. One of the main purposes of these plots is to discover suitable alternatives to Napier grass for growing as mulching grasses; with due regard to the essential characteristics needed, all prospective mulch grasses have been observed over the past six years for ease of establishment, vigour, drought resistance, productivity and persistence when laid as a mulch. The search was narrowed during the Long Rains when six selected species and three varieties of Elephant grass were planted into field plots each a quarter-acre in extent. Parallel selection and replanting on a smaller scale was effected on the plots at the North Kitito Sub-station.

The programme of replanting mulch production areas was continued and the acreage was extended by 15 acres at the top end of the estate, where temporary grass leys are being replaced by experimental coffee and Napier grass on the slopes of the ridge. The reverse process is being applied to the lower end of the farm.

The Demonstration Farm, Rukera Estate: General Description

The map inside the back cover shows the boundaries of the demonstration farm. The original Rukera Estate, which was purchased by Government in January, 1949, consisted of 329 acres and this area has been subdivided to provide:—

- (a) Additional land for the Research Station. All land north of the central ridge road (approximately 52 acres) was added to Jacaranda Estate to increase land available for experimental work.
- (b) A site was provided for the District Headquarters of the Soil Conservation Service (16 acres).
- (c) A site was provided for the Fruit Sub-station (11 acres).

The area available for development as a demonstration farm was thus approximately 250 acres.

The futility of attempting to carry out field experiments, involving a multitude of small plots, and demonstration work, including costing of operations, on the same land was early apparent on Jacaranda Estate and, for this reason alone, the acquisition of Rukera Estate was of the utmost importance in that it gave the Coffee Services the opportunity to separate these two closely related but nevertheless conflicting activities. On Jacaranda Estate the field experiments are the first consideration and no effort is spared to ensure that these experiments give real and valid answers. For obvious reasons, accuracy of treatments and measurement of yields and other factors are of paramount importance and, further, treatments are drawn up to evaluate effects singly or in combination so that the range of possibilities is covered. Some of these may bear no relation to present or future practice, but are required for purely technical reasons.

Sometimes the results of research are immediately applicable in practice but more frequently these results require modification or the modification of associated practices in the farm economy before they can be introduced. The demonstration farm thus gives the station staff the opportunity to try out and co-ordinate practices on a commercial scale. The extent to which this is successfully achieved will be a measure of the extension or demonstration value of the farm.

The function of the demonstration farm was described in detail in the Coffee Board Bulletin, in the January and March, 1953, editions. The aims of the farm were defined as follows:—

1. To give facilities for the demonstration and co-ordination into local estate practice of results obtained from Coffee Research Station investigations.

2. Bearing in mind the need (for long-term economic reasons) to devise a more extensive and wider agricultural effort on many estates in the East Rift area, the demonstration farm will provide an opportunity for practical studies.
3. By the use of treated and untreated observation strips to demonstrate effects of certain treatments as an extension of more detailed investigation on Jacaranda.
4. To disseminate cultural advice to visitors, thereby reducing considerably the amount of time spent in this way by officers engaged on investigational work.
5. As the farm will be self-accounting, costings will be fully valid. It is the intention to have the farm accounts supervised by professional farm accountants and accounts will be kept and presented in the same manner as is adopted on the best local estates.
6. To give an opportunity to study practical details in the composite farming system being developed.
7. To give facilities for general training.

During the intervening three years good progress has been made towards fulfilling the first two aims. The total acreage is now devoted to the following purposes:—

Regenerated mature coffee	74 acres
New planted coffee (six acres in bearing)	15 "
Napier grass plots for mulch	40 "
Irrigated fodder terraces and pasture	7 "
Ensilage crops (on ley areas and future coffee plots)	10 "
Rhodes and Star grass leys	5 "
Permanent pasture	38 "
Oranges (Washington Navel variety)	2 "

The residual acreage comprises roads, buildings, trees, vleis and riverine flats. With the exception of the last two categories of land every acre within the boundaries has been brought into production.

The intention is to maintain some 80 acres of bearing coffee as the main enterprise. A comprehensive depth survey by the soil probe method has indicated that portions of the established coffee are sited on soil of inadequate depth, mainly at the lower end of the farm. As the new coffee reaches the age of three years and is allowed to bear crops, an equivalent area on unsuitable soil is uprooted: six acres is the extent of such redistribution to date. During this transition period some delay is inevitable before the full acreage of Napier grass and ley can be attained.

Most of the single-stem blocks have been converted to a multiple-stem pruning system. Attention has been paid to timing the conversion and change from first to second cycle with the object of retaining at least 60 acres in full bearing every year.

A small grade Guernsey herd has been built up from a foundation stock of Guernsey/Boran half-bred heifers, inseminated with pure-bred Guernsey sperm. Second generation progeny are now in milk. The herd is fed in yards during the two dry seasons with ensilage and fodder grown on irrigated bench terraces. The latter are now in full production with crops of lucerne, bananas and Napier grass. The irrigated area has recently been extended by piping water to a further terraced area and two small leys. The fencing programme, designed to enclose all permanent pasture and leys, is nearing completion. In order to increase the grazing capacity it is planned to extract flood flow from the river to provide supplementary irrigation during the rains to the pastures at the top end of the farm.

The Washington Navel oranges, planted on irrigated bench terraces, constitute a third minor enterprise. The first crop of 7,600 lb. of fruit was harvested during 1955.

The initial development programme is now nearly complete; the following capital improvements have now been installed within a compact administrative area:—

Farm buildings, consisting of an office, coffee factory, drying ground and store, food store, tool store, workshop, tractor and implement sheds, garage, petrol store, dairy buildings including a milking parlour with machine milking, cattle yards, fodder barn, calf pen, covered night yards and silos. Manager's house and African quarters.

Borehole and storage tanks, with main irrigation lines to fruit and fodder bench terraces in permanent G.I. piping, with lateral gravity feeders in two-inch mobile, aluminium piping.

Farm implements, including Ferguson TEC tractor with Towner disc-harrow and non-tipping trailer. Other Ferguson implements will serve both estates; Fiat 25c crawler tractor.

Since the farm was purchased account has been kept of total running and capital expenses. A new system of accounts was brought into operation on July 1 which will provide data on the component costs of the various farming operations of each enterprise. This constitutes a most vital function of the demonstration farm.

Rukera Estate—1956-57 Season

Development

The fencing programme was completed during the year: all leys, permanent and riverine pastures are now enclosed. A new road of access along the river valley was constructed to permit manuring and full utilization of the pastures bordering the river. The fodder production capacity was increased by the planting of a further three acres of Napier grass on irrigable terraces and the purchase of irrigation equipment for use on these terraces and on paddocks nearby.

Labour quarters and cattle sheds were reroofed in permanent materials.

The planting programme was continued with a further $2\frac{1}{2}$ acres of new coffee planted in April, bringing the total coffee area to 91 acres.

Coffee Crop: 1956-57

Rainfall—1.1.56 to 31.12.56 (inches)	34.22
Acreage in production	78
Clean coffee (tons)	25.33
Mbuni (lb.)	16,013

<i>Classifications</i>	<i>lb.</i>	<i>Percentages</i>
Class 3	29,270	51.55
„ 4	1,286	2.26
„ 5	14,098	24.84
„ 6	774	1.36
„ 7	1,021	1.80
„ 8	1,960	3.45
„ 9	3,162	5.57
„ 10	4,109	7.24
„ 12	1,030	1.81
„ 13	37	.06
	56,747 lb.	

1,336 lb. of parchment were prepared as coffee seed from two clonal blocks on the estate: a clean coffee allowance for this has been added to the total weight of the crop given above.

Other Enterprises

Rainfall was sufficiently distributed to maintain the grazing areas in condition for most of the year. Nevertheless a distinctly limited acreage implies that the herd numbers should be slowly reduced as milk yields increase. In pursuit of this policy 12 cows were culled and replaced by six higher grade heifers towards the end of the year. A pedigree bull calf of the same strain was also purchased in March.

Approximately 11,000 lb. of good quality oranges were picked during the second crop cycle from two acres of Washington Navel trees.

Fruit Sub-station

On Mr. Evans's transfer to the Horticultural Research Station at Thika work on the station was scaled down, leaving certain lines of study to be continued for three or four years. When these have been concluded it is anticipated that the land will revert to Rukera Estate.

ADVISORY AND EXTENSION SERVICES

"There is no doubt whatsoever that much good would accrue from a greater intensification of this effort in the battle for improved production." Although production has soared in the intervening two years this statement (contained in the 1955 Annual Report) is as true today as it was then. Unfortunately efforts to increase the tempo of the service have been somewhat frustrated by periods of staff shortage, sickness and limited travelling funds. Nevertheless much has been achieved in this diverse field. The number of visitors and letters seeking advice remains at a high level. Advisory tours to all districts in the three regions were undertaken during the course of the year. Several parties of students and groups of African growers have visited the Station. Messrs. Jones and Robinson delivered the annual coffee lectures at Egerton College. Station staff were on hand during the Royal Show in October to discuss coffee matters with visitors to the Board's stand at Mitchell Park.

A major event in the "extension" calendar was the Coffee Planters' Day held at the Research Station on July 26. The second edition of the "Guide to the Coffee Research Station", first published in 1951, was produced for the occasion, in a revised and enlarged form.

The notes provided in the Bulletin under the heading "Better Coffee Farming" were maintained and, according to reports, continue to serve as a very valuable medium for bringing advice and information to the planter.

PUBLICATIONS

The following articles were published in the Monthly Bulletin of the Coffee Board of Kenya:—

VOL. XXI

- April** "The Effect of Rainfall and Other Factors on Coffee Production and Yields in Kenya 1947-1955," by J. B. D. Robinson and A. R. Melville.
- May** "Annual Report for Coffee Team Services," by P. A. Jones.
- June** "A Note on Onion Flavour," by P. A. Jones and C. R. Devonshire.
"Extracts from the Annual Report of the Agricultural Chemist (Coffee Services), 1954 and 1955," by J. B. D. Robinson.
- September** "Recent Results of Experiments with Weedkillers in Coffee," by J. B. D. Robinson.
- October** "Coffee Lacebug in the Central Province," by D. J. McCrae.
- November** "Notes on the Varieties of *Coffea arabica* in Kenya," by P. A. Jones.
- December** "Extracts from the Reports of the Plant Pathologist and Physiologist (Coffee Services) for the Years 1954 and 1955," by R. W. Rayner.

VOL. XXII

- January** "Extracts from the Reports of the Agricultural Officer (Coffee Services) for the Years 1954 and 1955," by P. A. Jones.

Articles published in other journals during the year were as follows:—

- Robinson, J. B. D. The Influence of Fertilizers and Manures on the pH reaction of a coffee soil. *E. Afr. agric. J.*, 1956, **22**, 76.
- Robinson, J. B. D. Rapid Kjeldahl nitrogen digestion of coffee-leaf material by the Permanganate method. *The Analyst*, 1956, **81**, 316.
- Robinson, J. B. D. Weed Control with chemicals in Arabica coffee. A brief review of results from the Coffee Research Station, Ruiru. 1957 (Jan.), First East African Herbicide Conference, E.A.A.F.R.O.
- Rayner, R. W., and Bock, K. R. Control of Coffee Berry Disease in Kenya, Letter to *Nature*, 1956, **178**, No. 4526, 217.

FIELD INVESTIGATIONS

CULTIVATION TRIALS

<i>Site:</i>	Moderate slope of 1-8% which probably had suffered considerable erosion in the past but which is now protected with narrow-based absorption terraces.
<i>Date Planted:</i>	Before 1920.
<i>Spacing:</i>	10 ft. x 10 ft.
<i>Shade:</i>	None.
<i>Pruning System:</i>	Converted from single-stem pruning to multiple stem by stumping in 1944.
<i>Trial Commenced:</i>	1947.

Objects

This trial was laid down in 1947 to investigate the following aspects of coffee culture:—

1. The replacement of hand-forking by mechanized cultivation in coffee plantations.
2. The management of weeds growing in coffee with special reference to frequency of weeding and depth of cultivations.
3. The value of incorporating organic matter into the soil of coffee plantations.
4. The effects of sub-soiling.
5. A study of soil structure changes under combinations of these treatments.

Layout

The initial design was a partially confounded 3 x 3 x 3 x 3 factorial layout with 81 main plots each of 40 trees in two rows of 20. The main plots were split and organic matter was added to one of each pair of sub-plots.

Treatments

Main Plots:

Weed Control	W ₀	Weed growth fully controlled at all seasons.	
	W ₁	Weed growth slashed during the rains and turned in at the end of each rains.	
	W ₂	Weed growth unrestricted during the rains and turned in at the end of each rains.	
Implement	T ₀	Forked hand hoe known locally as a forked jembe.	} Depth of cultivation limited to 3"-4" from January, 1952.
	T ₁	Disc-harrow.	
	T ₂	Mouldboard plough.	
Depth of Cultivation	D ₀	All cultivations to 2"-3".	
	D ₁	Cultivation to 2"-3" in the rains and one deep cultivation in the dry seasons.	
	D ₂	All cultivations to 5"-6".	
Sub-soiling	S ₀	No sub-soiling.	
	S ₁	All row sub-soiling every four years, i.e. one side of each row every second year.	
	S ₂	All row sub-soiling every two years, i.e. one side of each row each year.	

Sub-Plot Treatments:

±C	1 4-gallon tin (<i>ndebe</i>) per tree each year—approximately 3½ tons per acre. From 1948.
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Results

The main findings during the years 1947-1951 are summarized in Table I, which shows the great importance of weed control during the rains, and on the clean-weeded plots the superiority of the hand fork over either the mouldboard plough or the disc-harrow (see Table IV). The sub-plots to which organic matter had been added yielded slightly more than those not receiving this treatment.

Sub-soiling proved to be of no advantage and it was clearly undesirable to cultivate deeply between coffee trees which have an important root system in the top few feet of soil as well as roots penetrating to great depth.

The first five years of this trial were fully reported by H. C. Pereira and P. A. Jones in the *Empire Journal of Experimental Agriculture* (1954).

TABLE I
Summary of yield results 1947-1951
(Total yields for five years in cwt. clean coffee per acre)

Main plots		Depth of Cultivation	
Type of Implement			
T ₀ Forked hand hoe	27.91	D ₀ Shallow only (2-3 in.)	26.43
T ₁ Tractor disc-harrow	26.06	D ₁ Shallow plus once deep	27.46
T ₂ Tractor mouldboard plough	27.64	D ₂ Deep only (5-6 in.)	27.71
(T ₀ > T ₁ at p = 0.01)		(Differences not significant)	
T ₂ > T ₁ at p = 0.05)			
Weed Control During the Rains		Sub-soiling	
W ₀ Clean weeded	35.29	S ₀ No sub-soiling	26.81
W ₁ Weeds slashed	25.65	S ₁ Biennial sub-soiling	27.12
W ₂ Tall weeds	20.65	S ₂ Annual sub-soiling	27.70
(W ₀ > W ₁ > W ₂ at p = 0.001)		(Differences not significant)	
Sub-plots			
(Total yields for four years 1948-1951)			
C ₀ No manure		20.98	
C ₁ Annual dressing of one 4-gallon tin/tree		21.47	
(Differences not significant)			

In January, 1952, after five crops had been recorded, the sub-soiling and depth of cultivation contrasts were discontinued and the trial was reduced to six blocks of nine main plots each, with the object of testing the factorial combination of three methods of cultivation (T₀, T₁, T₂) and three degrees of weed control (W₀, W₁, W₂) in the presence and absence of added organic matter ($\pm$ C). The size of the trial was reduced again following the 1954 crop and now consists of only three blocks, each of nine main plots, but the treatments have remained unaltered since 1952.

Following the 1951 crop, conversion to a new multiple-stem cycle was begun by removing two of the three heads, cutting up the third severely and selecting three strong suckers on each tree. Following the 1956 crop, conversion was begun in a similar manner but this time only one old head was removed while the remaining two heads were pruned to leave 3 ft. of bearing wood on each head.

TABLE II
Summary of yield responses to weeding treatments 1947-1956
(Yields in cwt. clean coffee per acre)

Treatment	Total 1947-51	1952	1953	1954	1955	1956	10-year total	Mean annual yield	% W ₀
W ₀ Clean weeded	35.29	4.16	4.85	15.69	16.69	10.21	86.89	8.69	100
W ₁ Weeds slashed	25.65	2.79	4.19	13.49	12.86	8.31	67.29	6.73	77
W ₂ Tall weeds	20.65	2.61	3.03	11.49	10.04	3.13	50.95	5.10	59
Least Significant Difference									
p=0.05	1.40	0.91	0.40	0.86	0.80	1.48			
p=0.01	1.84	1.22	0.53	1.15	1.10	2.04			
C. of V. %		30.0	9.6	6.7	12.9	20.5			

The responses during the years 1952-1956 have confirmed and amplified the findings of the first period, for while during the first five years the clean-weeded (W_0) plots yielded approximately 3 cwt. of clean coffee a year more than the plots weeded only at the end of each rains (W_2), during the second period this difference increased to 4 cwt. of clean coffee a year. It is notable that in every year of this trial there has been a highly significant increase in yield of clean coffee as a result of clean weeding. The most striking responses occurred in the 1956 crop in which the clean-weeded plots (W_0) yielded over 300% more than the tall weed plots (W_2). The yields of clean coffee from plots on which weeds were slashed during the rains (W_1) lay about half-way between those of the clean-weeded plots (W_0) and those of the plots on which the weeds were uncontrolled during the rains (W_2). From the final column of Table II, which summarizes the results of ten years, it may be seen that if the clean-weeded plots (W_0) are taken as a standard there has been a crop loss of 23% on the slashed plots (W_1) and a loss of 41% where weed growth was allowed during the rains (W_2).

TABLE III
Summary of yield responses to type of implement 1947-1956
(Yields in cwt. clean coffee per acre)

Treatment	Total 1947-51	1952	1953	1954	1955	1956	10-year total	Mean annual yield	% T_0
T_0 Forked hand hoe	27.91	3.32	3.97	14.25	12.84	7.01	69.30	6.93	100
T_1 Disc-harrow	26.06	3.08	4.19	13.52	12.86	7.60	67.21	6.72	97
T_2 Mouldboard plough	27.64	3.16	3.91	12.91	13.89	7.04	68.55	6.86	99
Least Significant Difference									
$p = 0.05$	1.40	0.91	0.40	0.86	0.80	1.48			
$p = 0.01$	1.84	1.22	0.53	1.15	1.10	2.04			
C. of V. %		30.0	9.6	6.7	12.9	20.5			

Differences between the yields of plots cultivated with the three implements are only clear on the (W_0) plots which are cultivated several times each rains. The (W_1) and (W_2) plots are cultivated after each rains and thus only twice a year. In each of the five-year periods, and so in the ten-year aggregate, the yields from the (W_0) plots cultivated with a forked hand hoe (T_0) have been about 10% greater than the yields from plots cultivated with either the disc-harrow (T_1) or the plough (T_2). This implies a difference of a little under 1 cwt. clean coffee a year.

TABLE IV
Summary of yield response to type of implement on clean-weeded plots (W_0)
(Yields in cwt. clean coffee per acre)

Treatment	1957-51 5-year total	1952-56 5-year total	1947-56 10-year total	Mean annual yield	% $T_0 W_0$
T_0 Forked hand hoe	39.15	54.78	93.93	9.39	100
T_1 Disc-harrow	32.94	50.66	83.60	8.36	89
T_2 Mouldboard plough	33.78	50.58	84.36	8.44	90
Least Significant Difference					
$p = 0.05$		2.53			
$p = 0.01$		3.40			

The organic matter addition (+C) used in this trial is the grey sunbaked, heavily leached product obtained from the cattle enclosures of the Masai stock owners and known locally as Athi Plains Manure. This material was chosen because it is highly valued by certain experienced coffee planters and also is available to coffee growers who may not have the stock to produce the composted manure familiar to farmers in the temperate regions.

The yield response to additions of one *ndebe* (4-gallon tin) of manure has been very irregular, for while very considerable yield increases attributable to the manure were recorded in 1952 and 1955, the same advantage has not been evident in other years.

TABLE V
Summary of yield response to one 4-gallon tin of cattle manure per tree each year
(Yields in cwt. clean coffee per acre)

Treatment	1948-51 4-year total	1952	1953	1954	1955	1956	1948-56 9-year total	Mean annual yield	% —C
+ C. 1 tin/tree	21.47	3.77	3.99	13.88	14.61	6.44	64.16	7.13	106
— C. Nil	20.98	2.60	4.05	13.24	11.79	7.99	60.65	6.74	100
Least Significant Difference									
p = 0.05	1.00	0.75	0.39	0.59	1.23	1.01			
p = 0.01	1.33	1.01	0.52	0.78	1.67	1.38			
C. of V. %		61.0	25.0	11.2	16.5	24.9			

Table V shows that over the nine years an application of in all about 32 tons of the Athi Plains Manure per acre has resulted in an increase in total yield of about 4½ cwt. clean coffee per acre. This overall increase of 6% would more than pay for the manure, but it is well to notice that other trials on this station, in which the coffee yield response to additions of organic matter are studied in detail, do not show similar yield increases. It seems possible that the response to manure is greater on the Cultivation Trial than on the Manurial Trials because the former is on a more eroded site than are the latter.

References

- PEREIRA, H. C. *A.R. Dept. Agric., Kenya*, 1947, **2**, 117.
 PEREIRA, H. C. and JONES, P. A. Field Responses by Kenya Coffee to Fertilizers, Manures and Mulches. *Emp. J. exp. Agric.*, 1954a, **22**, 23.
 —————, A Tillage Study in Kenya Coffee—Part I. *Emp. J. exp. Agric.*, 1954b, **22**, 231.
 —————, A Tillage Study in Kenya Coffee—Part II. *Emp. J. exp. Agric.*, 1954c, **22**, 324.

ROTARY CULTIVATION IN COFFEE

The results of the Cultivation Trial soon made it clear that in the drier coffee areas of Kenya efficient weed control during the rains leads to substantially higher yields than those obtained when weeding is left until the end of the rains. Neither of the tractor-drawn implements was as satisfactory as the forked hand hoe, so the problem of mechanical cultivation remained unsolved. It was for this reason that in 1953 modifications were made to a tractor-mounted rotary hoe so that it would produce large clods of soil similar to those produced by the forked hand hoe. Preliminary tests suggested that the modified rotary hoe was successful enough to be compared against a forked hand hoe in a yield-recorded trial.

Details of this preliminary work here was given by Pereira and Jones in a paper in the *Empire Journal of Experimental Agriculture* (1954).

ROTAVATOR TRIAL

Site:	Level, deep fertile soil.
Date Planted:	Before 1920.
Spacing:	10ft. x 10ft.
Shade:	None.
Pruning System:	Single stem.
Trial Commenced:	December, 1953.

Objects

1. To test the long-term effects of a modified rotary hoe on the soil structure and yield of coffee.
2. To test the interrelationship of mulch and weed growth in their effect on the soil structure and yield of coffee.

Layout

A 2 x 2 x 2 factorial design in two replications of eight plots was laid down in December, 1953. Each plot consisted of a single row of trees. This trial is insufficiently replicated because when it was laid down there was no other coffee area available.

Treatments

Implement	R.	Modified rotary hoe.
	F.	Forked hand hoe.
Weed Control	W ₀	Weed growth fully controlled at all seasons.
	W ₂	Weed growth unrestricted during the rains but turned in at the end of each rains.
Mulch	±M	4½-ft. band of mulch in the tree rows. Modified in March, 1956, to a 7-ft. band of mulch in alternate inter-rows in alternate years.

Results

On all plots yields were low and highly variable in 1954 and 1956, because this whole area of coffee was in a most markedly biennial bearing condition. Following the 1956 crop all this coffee was very severely pruned to moderate the yield in 1957 and so, it is hoped, permit the trees to bear a fair crop in 1958.

TABLE VI
Yield Summary 1954-1956
(Yield in cwt. clean coffee per acre)

Treatment	1954			1955			1954-1956 3-year totals		
	Cwt./ acre	%	% of Mean	Cwt./ acre	%	% of Mean	Cwt./ acre	%	% of Mean
<i>Implement</i>									
R Rotary hoe	1.60	258	144	16.07	96	98	17.92	103	101
F Fork	0.62	100	56	16.76	100	102	17.42	100	99
<i>Weeding</i>									
W ₀ Clean weeding	0.92	71	83	17.49	114	107	18.64	112	105
W ₂ Tall weeds	1.30	100	117	15.34	100	93	16.70	100	95
<i>Mulching</i>									
+M Alternate row mulch	1.48	220	133	18.90	136	115	20.55	139	116
-M No mulch	0.74	100	67	13.93	100	85	14.79	100	84
Mean yield	1.11		100	16.42		100	17.67		100
C. of V. %	53.0			9.2			7.5		
<i>Least Significant Difference</i>									
p = 0.05	0.68			1.74			1.53		
p = 0.01	0.99			2.54			2.22		
p = 0.001	—			3.81			3.34		

Table VI shows that, although the yields from the plots cultivated with a modified rotavator were highly significantly greater than those cultivated with a forked hand hoe in 1954, in the three-year totals there was no significant difference between implements.

In 1955 the weed competition on the W₂ plots reduced the yield of clean coffee by 14% and for the three-year total the depression in yield is shown to be 12%.

The important part played by mulch under local conditions is shown by the overall yield increase of 39% attributable to mulch.

TABLE VII
The interaction of mulch and weeds
Total yields for three years 1954-1956

	Mulched	Unmulched	Difference
Weeding			
W ₀ Clean weeding	21.51	16.11	+5.40
W ₂ Tall weeds	19.93	13.46	+6.47
Difference	+1.58	+2.65	
Least Significant Difference	p = 0.05 2.14	p = 0.01 3.11	p = 0.001 4.67

Table VII shows that, while under either system of weed control mulch increased the yield of clean coffee very highly significantly, clean weeding led to a significant yield increase on the unmulched plots but not on the mulched plots.

These results throw light on the interrelation of mulch and weed control, for it has been evident that the mulch applied in March suppressed weed growth during the April-May rains and to a slight extent in the November rains as well. It is therefore to be expected that it is on the plots without mulch that the greatest responses to clean weeding are recorded.

References

- JONES, P. A. *Rotary Cultivation in Kenya Coffee*. Paper presented at C.C.T.A. Conference on the mechanisation of Agriculture, Entebbe, Uganda, 1955.
 ——— (ed.) *Guide to the Research Laboratories and Field Experiments on Jacaranda Estate*, 1956, 17.
 ——— *A.R. Dept. Agric., Kenya*. 1955, 2, 67.
 PEREIRA, H. C. and JONES, P. A. A Tillage Study in Kenya Coffee—Part II. *Emp. J. exp. Agric.* 1954, 22, 324.

IRRIGATION TRIAL

Site:	Irregular moderate slopes of fair depth and fertility. Formerly three replications of the Cultivation Trial.
Date Planted:	Before 1920.
Spacing:	10 ft. x 10 ft.
Shade:	None.
Pruning System:	Multiple stem converted from single stem in 1944 by stumping; conversions to new cycles following 1951 and 1956 crops.
Trial Commenced:	May, 1956.

Objects

1. To compare economy of water with economy of labour.
2. To study the effects on coffee yield of irrigating coffee at each of three seasons of the year.
3. To observe and record any physical or chemical changes in the soil following irrigation.

Layout

The time of irrigation is arranged in a 2 x 2 x 2 factorial design and the plots are split for the method of application. There are three replications. Each sub-plot consists of 20 trees.

Treatments

Main Treatments:

- (a) Irrigation towards the end of the Short Rains flood-flow period (December—early January).
- (b) Irrigation towards the end of the Long Rains flood-flow period (May—early June).
- (c) Irrigation during August—a “crop saver”.

Sub-treatments:

O Overhead irrigation.

G Ground irrigation to ponds 4 ft. x 4 ft. around each tree.

The amount of water to apply:

The deficit between the moisture evaporated and the rainfall received is calculated from the last occasion when the top ten feet of the soil profile were at field capacity. Irrigation is then applied to make up any deficit. (Pereira 1957.)

Fuller details of the treatments and the irrigation equipment used have been given by Jones and Wallis (1957).

Results

There was no significant difference between treatments in the yields of the 1956 crop, which was not surprising as the first irrigation (b) was not applied until May, 1956, when the crop was nearly ready for picking.

References

- JONES, P. A. and WALLIS, J. A. N. Irrigation Experiments at the Coffee Research Station, Ruiru, Kenya. *E. Afr. agric. J.*, 1957, **22**, 186.
- PEREIRA, H. C. The Seasonal Assessment of Water Needs in the Irrigation of Coffee. *E. Afr. agric. J.*, 1957, **22**, 188.
- Field Measurements of Water Use for Irrigation Control in Kenya Coffee. *J. agric. Sci.*, 1957, **49**, 459.

MULCHING AND SOIL REGENERATION TRIAL

Site:	Fair to moderate slopes which had been severely eroded before this trial was laid down.
Date Planted:	Before 1920.
Spacing:	10 ft. x 10 ft.
Shade:	None.
Pruning System:	Multiple stem converted from single stem in 1945; conversion to new multiple-stem cycles was begun after the 1951 and 1956 crops.
Trial Commenced:	1949.

Objects

1. To test methods of improving the structure of eroded coffee soils.
2. To determine the best time and degree of applications of a grass mulch as measured by the coffee yield response and soil structure assessments.
3. To determine if cattle manure applied under the favourable moisture conditions provided by grass mulch led to improved yields of coffee.
4. To observe the possible interaction of nitrogenous fertilizers with mulch and cattle manure.
5. To compare the relative efficiency of adding nitrogen to the soil in the ammonium or nitrate form.
6. To establish a range of soil conditions for soil nitrogen studies.

Layout

The design is a 4 x 2 x 4 factorial with three second order interactions confounded with blocks. There are two replications of 32 plots arranged in blocks of eight plots, each consisting of two rows of ten trees. In 1956 the plots of one complete replication were split to allow the incorporation of a magnesium fertilizer treatment.

Treatments

Main Plots:

Mulching—from 1950.

(1) Nil.

a. All inter-rows mulched before the Long Rains—March.

b. Alternate inter-rows mulched before the Long Rains—March.

ab. All inter-rows mulched after the Long Rains—June-July.

The mulch is Napier grass laid in 7-ft. bands of 4 inches settled depth between the tree rows.

Organic Manure—from 1949.

± C Nil versus 1 *ndebe* (4-gallon tin) of cattle manure 1949-1953. (Approx. 3½ tons per acre.)
2 *ndebe* of cattle manure from 1954. (Approx. 7 tons per acre.)

The composted manure is produced on the station and is comparable with the farmyard manure of temperate countries.

Nitrogenous fertilizer—from 1951.

- d. 1951-1953 23 lb. nitrogen as 1 cwt. ammonium sulphate.
from 1954 46 lb. nitrogen as 2 cwt. ammonium sulphate.
- e. 1951-1953 23 lb. nitrogen as 144 lb. sodium nitrate.
from 1954 46 lb. nitrogen as 288 lb. sodium nitrate.
- de. 1951-1953 23 lb. nitrogen as nitrochalk.
from 1954 46 lb. nitrogen as 1 cwt. ammonium sulphate + 144 lb. sodium nitrate.

Sub-plots. Magnesium fertilizer—from 1956—on one replication only.
± Mg. Nil versus 1 cwt. of Kieserite per acre.

During the first two years of the trial the fertilizer treatments could not be applied as the appropriate chemicals were unavailable. After the 1953 crop the rates of application of nitrogenous fertilizer and cattle manure were doubled, since other trials on the station had indicated that annual dressings of 23 lb. of nitrogen per acre and 3½-4 tons of composted manure per acre were insufficient to affect coffee yields. The times of mulch application were changed after the 1949 season since it had been shown on small observation plots that pre-rains mulch was more effective than mulch applied after the rains.

Results

TABLE VIII
1949 Yields
(Yield in cwt. clean coffee per acre)

<i>No mulch</i>	<i>Alternate inter-rows mulched post rains</i>	<i>All inter-rows mulched post rains</i>	<i>Least Signifi- cant Difference</i>
<i>Mean of 32 plots</i>	<i>Mean of 16 plots</i>	<i>Mean of 16 plots</i>	<i>p=0.05</i>
4.28	4.37	4.84	0.51

Since the treatments applied in 1949 were different from those in subsequent years, and as they did not give rise to any significant difference between yields, these figures have been omitted from the summary tables which follow.

The most striking response of this trial has been to the application of grass mulch. Table IX shows that for the whole period 1950-1956 the yield of clean coffee from plots receiving mulch in each row has amounted to about 130% of the yield from the unmulched plots. In terms of clean coffee per acre this has meant an increase of just over 2 cwt. a year. However, this valuable yield increase was not recorded in 1952 or in 1955. The 1952 yields were low and variable because the coffee was in the process of being converted to a new multiple-stem cycle, but this was not the case in 1955 when the yield from the unmulched plots was almost twice that of the mulched plots. It is thought that this was the result, in part at least, of the high yields recorded from the mulched plots in the previous years. A contributory factor may have been that, as a pruning treatment is not included in this trial, the whole area is treated uniformly, which is clearly not the best way to treat trees in plots bearing at such different levels. It is intended to introduce some form of rational pruning treatment into this trial in the near future.

TABLE X
The main effects of mulch with and without composted manure
(Mean annual yields in cwt. clean coffee per acre)

Mulch treatment	Manure	1950-1953		1954-1956		1950-1956			
7-ft. bands, 4" deep	C.	± C.	Mean	± C.	Mean	± C.	Mean	% (1)-C	% (1):
(1) No mulch	+ C	4.50		12.50		7.93		114	
	- C	3.99		10.97		6.98		100	
	Mean		4.24		11.73		7.45		100
a. All inter-rows pre Long Rains. (March)	+C	5.95		15.53		10.05		144	
	-C	5.58		14.64		9.46		136	
	Mean		5.76		15.08		9.76		131
b. Alternate inter-rows pre Long Rains. (March)	+C	5.12		14.56		9.16		131	
	-C	5.19		14.29		9.09		130	
	Mean		5.16		14.42		9.13		123
ab. All inter-rows post Long Rains. (July)	+C	5.07		15.26		9.44		135	
	-C	5.51		15.26		9.69		139	
	Mean		5.29		15.26		9.56		128
Least Significant Difference									
p = 0.05		0.61	0.43	1.19	0.84	0.75	0.53		
p = 0.01		0.82	0.58	1.60	1.13	1.02	0.72		
C. of V. %			11.07		8.2		8.2		

The results of the 1950 and 1951 harvests supported the view that the pre-rains mulch applications were more effective than the post-rains treatments (Pereira and Jones, 1954) but this result was not confirmed by later crops which, when taken together, suggest that the great yield increases which follow the use of mulch in coffee are little influenced by the time at which the mulch is applied. An explanation for this apparent inconsistency may be that, while in the early years of this trial the value of the mulch was directly proportional to the amount on the ground at the beginning of the main rains (April), in latter years the cumulative benefits of mulching were such that it mattered little whether the mulch was most effective before the main rains in April or before the second rains which began in November. Possibly mulch applied after the main rains in July (ab) may be considered as much a pre-rains treatment as the applications (a) and (b) which go on in March and are known as the pre- (Long) rains treatment.

Napier grass (*Pennisetum purpureum*) has been used as the mulching material throughout this trial. It has been found that to apply mulch in 7-ft. bands 4 in. deep between every row of an acre of coffee requires about ten tons of oven dry grass.

TABLE X
Weight of grass mulch applied per acre
(Mulch band 7 ft. wide and 4 in. deep between all rows of a 10 ft. × 10 ft. plantation)

Year and Time of Application	Oven dry weight of grass in tons	N content lb.	P content lb.	K content lb.
PEREIRA and JONES (1954)				
1949. Post-rains July	10.0	88	26	
1950. Post-rains May	11.2	220	65	
1951. Pre-rains March	9.3	152	47	
1951. Post-rains June	5.3	143	32	
ROBINSON (1955)				
1954. Sample A	10.0	109	19	1,197
Sample B	10.0			934

Table X, which is derived from the paper by Pereira and Jones in the *Empire Journal of Experimental Agriculture*, and the 1954 *Annual Report of the Agricultural Chemist* (Coffee Services), gives an analysis of the material applied in the first four years of the trial. There is no reason to suppose that analyses of subsequent applications would not have given similar figures. The chemical analysis of Napier grass material has shown that in applying ten tons of oven dry material per acre the added potassium may amount to 800—1,200 lb. K per acre, which, if applied regularly, would gradually reduce the proportion of magnesium and possibly calcium in the soil which would be readily available to the coffee. This condition appeared to have been reached on this trial in 1956 when according to a visual assessment of the prevalence of iron and iron/magnesium leaf chlorosis this condition was highly correlated with the presence and degree of mulching.

TABLE XI

The relationship between the use of mulch and the presence of "herringbone leaf chlorosis" and "fine fishnet leaf chlorosis"

(Mean score per 20-tree plot—16 replications)

	No Mulch	Pre Long Rains—March		Post Long Rains. July
		Alternate inter-rows (b)	All inter- rows (a)	All inter- rows (ab)
"Herringbone chlorosis" A. Magnesium deficiency	0.13	9.25	10.50	19.81
Least Significant Difference				
p = 0.05			3.42	
p = 0.01			4.61	
p = 0.001			6.14	
"Fine fishnet chlorosis" B. Iron deficiency	1.63	12.38	21.38	21.69
Least Significant Difference				
p = 0.05			3.78	
p = 0.01			5.11	
p = 0.001			6.79	
Correlation coefficient between A and B		+0.700		

Key to scoring per tree : 0 = all leaves normal;

1 = some chlorosis;

2 = severe chlorosis.

This aspect of the trial has been fully reported by Robinson and Chenery (1958) and has led to the inclusion of the magnesium (Mg) treatment to sub-plots in one complete replication of the trial.

The effect of the grass mulch on soil structure has been described by Pereira and Jones (1954), who showed that the water percolation rate (under 1 cm. constant head) through soil taken from plots which had received mulch between every row for two years was higher than the rate through soil from an adjacent area which had been under Napier grass for six years following coffee. The proportion of water stable soil aggregates over $\frac{1}{2}$ mm. diameter was shown to be similar and the percolation rate under artificial rainfall of 6 in. per hour was equally good and was just under 6 in. an hour.

TABLE XII
Mulch x Nitrogenous Fertilizer Interaction Table
(Mean annual yields in cwt. clean coffee per acre)

1951-1953	Nitrogen at the rate of 23 lb./acre/annum				Mean yields for mulch treatments
Mulch treatment	No nitrogen	Ammonium form	Nitrate form	$\frac{1}{2}$ Ammonium $\frac{1}{2}$ Nitrate	
No mulch	5.06	5.44	6.22	4.87	5.40
All inter-rows pre Long Rains March	7.31	6.70	7.48	7.22	7.18
Alternate inter-rows pre Long Rains March	6.11	6.63	7.27	6.05	6.52
All inter-rows post Long Rains July	6.43	7.06	6.64	7.14	6.82
Mean yields for fertilizer treatments	6.23	6.55	6.90	6.32	6.48
Least Significant Difference	Within the table Marginal means	p = 0.05 p = 0.05	1.12 0.56	p = 0.01 p = 0.01	1.50 0.75
1954-1956	Nitrogen at the rate of 46 lb./acre/annum.				
No mulch	10.58	12.50	12.09	11.77	11.73
All inter-rows pre Long Rains March	14.47	14.87	15.44	15.56	15.08
Alternate inter-rows pre Long Rains March	13.59	14.70	15.48	13.92	14.42
All inter-rows post Long Rains July	14.83	15.14	15.41	15.67	15.26
Mean yields for fertilizer treatments	13.35	14.32	14.61	14.23	14.13
Least Significant Difference	Within the table Marginal means	p= 0.05 p= 0.05	1.68 0.84	p= 0.01 p= 0.01	2.26 1.13
1951-1956	Overall means for the six years				
No mulch	7.82	8.97	9.16	8.32	8.57
All inter-rows pre Long Rains March	10.89	10.79	11.46	11.39	11.13
Alternate inter-rows pre Long Rains March	9.85	10.66	11.38	9.98	10.47
All inter-rows post Long Rains July	10.63	11.10	11.03	11.41	11.04
Mean yields for fertilizer treatments	9.80	10.38	10.76	10.28	10.30
Least Significant Difference	Within the table Marginal means	p= 0.05 p= 0.05	1.28 0.64	p = 0.01 p = 0.01	1.72 0.86

Table XII shows that in neither of the periods 1951-1953, 1954-1956 has there been any consistent indication that the use of a nitrogenous fertilizer reduces the benefit of mulch, nor has the mulch affected the response to the fertilizers, but in the wet year of 1951 there was a significant negative interaction between the sulphate of ammonia (1 cwt./acre) treatment and the all inter-row pre-rains mulch treatment.

TABLE XIII

The main effects of nitrogenous fertilizers with and without composted manure
(Mean annual yield in cwt. clean coffee per acre)

<i>Treatments</i>		<i>23 lb. N./acre 1951-1953</i>		<i>46 lb. N./acre 1954-1956</i>		<i>1951-1956</i>			
<i>Fertilizer</i>	<i>manure C</i>	$\pm C$	<i>Mean</i>	$\pm C$	<i>Mean</i>	$\pm C$	<i>Mean</i>	$\frac{\%(1)}{(1)-C}$	$\frac{\%(1)}{\%}$
(1) No fertilizer	+C —C Mean	6.33 6.13 6.23		13.97 12.77 13.35		10.15 9.45 9.80		107 100	100
d. Nitrogen in the ammonium form	+C —C Mean	1 cwt. S/A acre 6.36 6.73 6.55		2 cwt. S/A acre 14.25 14.38 14.32		10.31 10.56 10.44		109 112	107
e. Nitrogen in the nitrate form	+C —C Mean	144 lb. N/S acre 6.87 6.93 6.90		288 lb. N/S acre 15.19 14.02 14.61		11.03 10.48 10.76		117 111	110
de. $\frac{1}{2}$ in ammonium form and $\frac{1}{2}$ in nitrate form	+C —C Mean	148 lb. N/C per acre 6.46 6.17 6.32		1 cwt. S/A 144 lb. N/S per acre 14.47 13.99 14.23		10.47 10.08 10.28		111 107	105
<i>Least Significant Difference</i> p = 0.05 p = 0.01 C. of V. %		0.79 1.07 11.9	0.56 0.75	1.19 1.60 8.2	0.84 1.13	0.75 1.02 9.0	0.53 0.72		

S/A = Sulphate of ammonia; N/S = Nitrate of soda; N/C = Nitrochalk.

The response to the various nitrogenous fertilizers has not been great or very consistent, but the last column of Table XIII does show that there has been a mean annual increase of nearly 1 cwt. clean coffee per acre. It seems surprising that the yield of plots under the treatment de ($\frac{1}{2}$ fertilizer in the ammonium form and $\frac{1}{2}$ in the nitrate form) should not be between treatment d (all fertilizer in the ammonium form) and treatment e (all fertilizer in the nitrate form), since the last has nearly always given the highest yields of the three treatments; however, though this difference is fairly consistent it does not approach statistical significance.

TABLE XIV

The main effect of composted manure on the yield of clean coffee
(Mean annual yields in cwt. clean coffee per acre)

<i>Treatment</i>	<i>1950-1953 1 tin/tree</i>	<i>1954-1956 2 tins/tree</i>	<i>1950-1956</i>	
+ C With manure	5.16	14.46	9.15	104%
— C Without manure	5.07	13.79	8.81	100%
<i>Least Significant Difference</i> p = 0.05 p = 0.01 C. of V. %	0.30 0.41 11.7	0.59 0.80 8.2	0.37 0.51 8.2	

In the presence of mulch composted cattle manure has not led to any significant increase in yield of clean coffee, for though it appears from Table XIV that the plots receiving an annual application of about seven tons of the manure per acre since 1954 have produced about $\frac{1}{2}$ cwt. clean coffee more than the plots not so treated, yet there has only been a 4% increase in yield over the seven years of this trial. Table IX shows that in the absence of mulch the use of manure has increased the coffee yield by 14%, but although this increase is to some extent additive in the case of all inter-row pre-rain mulch this is not the case with the other treatments. Thus the suggestion that substantial yield increases have not been recorded from the Manurial Trials because the manure is not mulched to give the optimum conditions is not supported in that the response to the composted manure is at its greatest in the absence of mulch.

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MANURIAL TRIAL I

- Site:** Level fertile area in good condition.
Date Planted: Before 1920.
Spacing: 10 ft. $\times$ 10 ft.
Shade: None.
Pruning System: Single stem until April, 1952, when conversion to a multiple-stem system was begun. Conversion was completed after the 1953 crop.
Trial Commenced: 1947.

Object

1. To determine the response of coffee to nitrogenous and phosphatic fertilizers and to organic matter.
2. To study the interaction of these materials as indicated by the coffee yield responses.

Layout

Four balanced replications of a partially confounded $3 \times 3 \times 3$ factorial design in 12 blocks of nine plots each of 20 trees in two rows of ten.

Following the 1951 crop only one original replication was retained and used to provide three replications of a 3×3 factorial design.

Treatments

Nitrogenous fertilizers — N_0 —Nil.

Applied early in the N_1 —(1947-1956) 23 lb. nitrogen per acre as 1 cwt. sulphate of ammonia.

Long Rains—April (from 1957) 46 lb. nitrogen per acre as 100 lb. urea.

N_2 —46 lb. nitrogen per acre as 2 cwt. sulphate of ammonia.

The N_1 treatment will be altered in 1957 so that the 1 cwt. per acre of sulphate of ammonia will be replaced by 100 lb./acre of urea so both the N_1 and N_2 treatments will supply 46 lb. N. per acre, but present in contrasting fertilizers. The rate of 46 lb. N. per acre was chosen because the evidence of many years' experiments indicated the 46 lb. N. per acre level is the minimum worthwhile application of nitrogenous fertilizer on coffee. Urea was chosen as it has recently become available at a cheaper rate per pound of nitrogen than sulphate of ammonia, moreover it has been shown that the repeated use of sulphate of ammonia could increase soil acidity considerably. (Robinson, 1956.) The N_2 treatment will be retained as sulphate of ammonia so that this characteristic may be studied further.

Phosphatic fertilizer 1947-1951.

Applied before the Long Rains—March P_0 —Nil.
 P_1 —2 cwt. per acre soda phosphate containing 45 lb. total P_2O_5 of which 7 lb. are citric soluble.
 P_2 — $3\frac{1}{2}$ cwt. per acre Uganda Rock Phosphate containing 90 lb. total P_2O_5 of which $3\frac{1}{2}$ lb. are citric soluble.

Where cattle manure and phosphatic fertilizers are to be applied to the same plot they are mixed together several weeks before application.

Composted Manure C_0 —Nil.
Applied before the Long Rains—March C_1 —1 4-gallon tin (*ndebe*) of composted manure per tree—approximately $3\frac{1}{2}$ tons/acre.
 C_2 2 4-gallon tins of composted manure per tree—approximately 7 tons/acre.

The manure is removed from covered yards in which cattle are kept by night bedded on Napier grass and other grasses. The resulting material is turned down a succession of open concrete stages to produce a final compost similar to the farmyard manure of temperate climates.

TABLE XV
An analysis of composted manure (Pereira 1950)

Water	40-50% of total weight
Nitrogen	2.5% of dry matter
Phosphate (P_2O_5)	0.8% of dry matter

Results

From the yields in the first five years of this trial, a summary of which appears in Table XVI it was evident that the composted manure had not increased the crop in any year; that sulphate of ammonia at 1 cwt./acre had not affected yields but at 2 cwt. per acre yields were greater in two of the five years and greater by 7% in the five-year aggregate total. In 1951 there was a clear negative interaction between composted manure and nitrogen, for although the 2 cwt. of sulphate of ammonia in treatment (N_2) produced a significant increase in crop in the absence of manure, this increase was not recorded when manure was present as well as sulphate of ammonia. Further details of results from this period were given by Pereira and Jones (1954).

TABLE XVI
Treatment response summary 1947-1951
(Total yields for the five years in cwt. clean coffee per acre)

Rate	Treatment					
	Nitrogen		Phosphate		Cattle Manure	
	Cwt.	% N_0	Cwt.	% P_0	Cwt.	% C_0
0	22.16	100	22.99	100	23.29	100
1	22.69	102	22.51	98	22.62	97
2	23.42	106	22.81	99	23.39	100
Least Significant Difference						
p = 0.05				1.25		
p = 0.01				1.65		

After the 1951 crop it was decided that only one complete replicate of the trial should be retained to study the response of coffee to composted manure and nitrogenous fertilizer each at three rates. Thus the phosphatic fertilizer treatments were abandoned but all plots were given a dressing at the rate of 3 cwt. per acre of Uganda Rock Phosphate and 2 cwt. per acre of Soda Phosphate in order to minimize any irregularities which might have been the result of applying phosphatic fertilizer to two-thirds of the plots for five years.

TABLE XVII
Summary of yield responses to a nitrogenous fertilizer and composted cattle manure
(Mean annual yields in cwt. clean coffee per acre)

Year	Nitrogenous fertilizer			Composted cattle manure			Mean annual yield	C. of V. %	Least Significant Difference	
	N ₀ Nil	N ₁ 23 lb. N/acre	N ₂ 46 lb. N/acre	C ₀ Nil	C ₁ 1 tin/ tree	C ₂ 2 tins/ tree			p = 0.05	p = 0.01
1947	5.53	5.32	5.52	5.51	5.47	5.40	5.46	10.1	0.26	0.36
1948	1.50	1.51	1.68	1.62	1.48	1.59	1.56	30.2	0.18	0.24
1949	2.05	1.89	2.20	2.07	2.05	2.03	2.05	36.0	0.49	0.65
1950	2.71	2.85	2.72	2.70	2.62	2.96	2.76	39.4	0.42	0.56
1951	10.37	11.12	11.30	11.39	11.00	10.41	10.93	16.5	0.84	1.12
1947-51	4.44	4.47	4.75	4.66	4.52	4.48	4.55	12.3	0.25	0.33
1952	4.39	5.63	5.84	4.42	4.79	6.65	5.29	24.1	1.27	1.75
1953	10.57	9.88	10.01	10.63	10.38	9.46	10.15	8.3	1.06	1.46
1954	5.58	5.91	7.11	5.85	6.02	6.73	6.20	17.3	1.07	1.48
1955	12.42	12.40	13.92	12.76	13.30	12.69	12.91	11.2	1.45	2.00
1956	3.91	5.32	4.85	5.08	4.06	4.93	4.69	30.4	1.42	1.96
1952-56	7.38	7.83	8.34	7.75	7.71	8.09	7.85	3.5	0.27	0.38
1947-56	5.91	6.15	6.55	6.20	6.12	6.29	6.20			

Table XVII summarizes the main treatment yields for the ten years 1947-1956 and shows that in the 1951-1956 period there has been a significant increase in yield attributable to the nitrogenous fertilizer in all years except 1953. During these years the application of 1 cwt. of sulphate of ammonia a year has increased the mean annual yield by $\frac{1}{2}$ cwt. an acre and twice the fertilizer application has led to just over twice the yield response. This suggests that the relationship between treatments is linear, which confirms the view that 46 lb. of Nitrogen per acre is by no means the economic limit of fertilizer application. In no season has there been a significant response to composted manure, when the yields are measured over all the nitrogen treatments, but from the five-year means it may be seen that the application of two 4-gallon tins of manure per tree each year has increased the mean annual yield by $\frac{1}{4}$ cwt. of clean coffee per acre—this difference is significant at $p=0.05$.

TABLE XVIII
The interaction of nitrogenous fertilizers with composted manure 1947-1956
(Yields expressed as percentages of the control treatment N₀C₀)

Period	Nitrogenous fertilizer lb. N/acre		Composted cattle manure—annual		
			C ₀ Nil	C ₁ 1 4-gall. tin/tree	C ₂ 2 4-gall. tins/tree
1947-51	N ₀	Nil	100	94	91
	N ₁	23 lb. N	96	96	97
	N ₂	46 lb. N	104	102	100
1952-56	N ₀	Nil	100	107	118
	N ₁	23 lb. N	115	117	113
	N ₂	46 lb. N	127	116	126
1947-56	N ₀	Nil	100	103	108
	N ₁	23 lb. N	108	109	106
	N ₂	46 lb. N	118	110	116

In Table XVIII the yields are expressed as percentages of the N_0C_0 (control) treatment and illustrate the nature of the negative interactions between manure and the nitrogenous fertilizers.

From the section referring to the period 1952-1956 it may be seen that the presence of manure did not affect the response to the nitrogenous fertilizer to the same marked extent that the application of the fertilizer reduced the response to composted manure. In the absence of the nitrogen additions there was a 7% (significant) increase in yield where one 4-gallon tin of manure was applied to each tree annually, and an 18% (highly significant) response to double the quantity. In the presence of the nitrogenous fertilizer the composted manure was of no value and indeed, at the N_2 level, the application of one 4-gallon tin of manure depressed the yield by 11% (highly significant). It appears from this trial that if manure is to be applied no nitrogenous fertilizer should be used, but, at the higher rate of application, greater yield increases may be expected from the use of nitrogenous fertilizer than have ever been recorded following the use of composted manure. These results must be regarded with caution since they do not quite agree with the 1951 negative interaction which was of the opposite type in that the use of manure nullified the response to the nitrogenous fertilizer.

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MANURIAL TRIAL II

Site:	Level area of good soil depth.
Date Planted:	Before 1920.
Spacing:	10 ft. $\times$ 10 ft.
Shade:	None.
Pruning System:	Single stem.
Trial commenced:	1950.

Object

To investigate the response of coffee to high rates of application of nitrogenous fertilizer, phosphatic fertilizer and composted manure.

Layout

Two replications of a $2 \times 2 \times 2$ factorial design were chosen for this trial as it filled the small area of coffee available. This design does not permit a precise study of the variables but does give a useful measure of the main treatment responses. Each plot consists of two rows of ten trees.

Treatments

Nitrogenous fertilizers	$\pm$ N. 92 lb. Nitrogen per acre as 4 cwt. sulphate of ammonia per acre 1950-1956, and 200 lb. urea in 1957.
Applied early in the Long Rains—April.	
The change over to urea in 1957 will bring this trial into line with current recommendations.	
Phosphatic fertilizer	$\pm$ P. as 2 cwt. double superphosphate 1950-1956.
Applied before the Long Rains—March.	Basic Slag will be used from 1957.

As there had been no response to double superphosphate during the seven years it will be replaced by Basic Slag in 1957 as it is thought that this may provide valuable minor nutrients as well as phosphorus.

Composted Manure ± C. 4 4-gallon tins (*ndebe*) per tree—approximately 14 tons per acre.
Applied before the

Long Rains—March.

The manure is produced on the estate as described under Manurial Trial I.

Results

TABLE XIX
Summary of results for 1950-1955
(Yields in cwt. clean coffee per acre)

<i>Treatment</i>	<i>1950</i>	<i>1951</i>	<i>1952</i>	<i>1953</i>	<i>1954</i>	<i>1955</i>	<i>Means of 6 crops</i>
No Nitrogenous fertilizer	3.05	4.46	14.48	6.07	2.35	15.16	7.60
4 cwt. sulphate of ammonia/acre	4.63	4.54	19.12	4.59	3.73	19.44	9.34
% response to fertilizer	+51.8%	+ 1.8%	+32.0%	-24.4%	+58.7%	+28.2%	+22.9%
No phosphatic fertilizer	4.15	4.62	17.06	5.44	3.13	17.37	8.63
2 cwt. double superphosphate/acre	3.54	4.38	16.55	5.22	2.95	17.23	8.31
% response to fertilizer	-14.7%	- 5.2%	- 3.0%	- 4.0%	- 5.8%	- 0.8%	- 3.7%
No composted manure	3.91	4.87	16.02	5.40	3.10	16.76	8.34
4 <i>ndebe</i> manure per tree/year	3.78	4.13	17.59	5.27	2.98	17.84	8.60
% response to composted manure	- 3.4%	-15.2%	- 9.8%	- 2.6%	- 3.9%	+ 6.4%	+ 3.1%
C. of V. %	22.5	34.6	18.2	35.0	39.0	6.5	5.4
<i>Least Significant Difference</i>							
p = 0.05	1.02	1.84	3.61	2.21	1.41	1.33	0.54
p = 0.01	1.51	2.73	5.34	3.28	2.09	1.97	0.80

The treatment means for the years 1950-1955 are presented in Table XIX. No figures are given for 1956 because the yields were so irregular that the coefficient of variation was 114%. In three of the six years there were substantial yield increases following the use of sulphate of ammonia at the rate of 4 cwt. per acre and in the six-year aggregate the annual response amounted to about $1\frac{2}{3}$ cwt. of clean coffee per acre.

Heavy annual dressings of double superphosphate and composted manure alone, together, and with sulphate of ammonia, have failed to affect the yields throughout the period 1950-1955.

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MANURIAL TRIAL III

Site: Level deep soil—formerly one complete replication of Manurial Trial I.
Date Planted: Before 1920.
Spacing: 10 ft. × 10 ft.
Shade: None.
Pruning System: Multiple stem converted from single stem in 1952 and 1953.
Trial commenced: 1952.

Object

1. To investigate the relative advantage of single and split nitrogenous fertilizer applications.
2. To obtain more information on the response by coffee to added nitrogen.

Layout

Three replications of a 3 × 3 factorial design were superimposed on one complete replication of Manurial Trial I. There are 20 trees per plot arranged in two rows of ten.

Treatments

Nitrogenous fertilizer:

N₀—Nil.

N₁—46 lb. Nitrogen per acre as 2 cwt./acre sulphate of ammonia (1952-1956).
100 lb. urea/acre from 1957.

N₂ 92 lb. Nitrogen per acre as 4 cwt./acre sulphate of ammonia (1952-1956).
200 lb. urea/acre from 1957.

Time of fertilizer application:

T₀—All applied early in the Long Rains—April.

T₁—All applied early in the Short Rains—November.

T₂—Half applied early in each rains—April and November.

Results

In 1952 crop yields were very low and variability very high. The yield data have been disregarded on account of the interference to the cropping reaction caused by conversion from a single-stem to a multiple-stem pruning system.

TABLE XX
Main Treatment Responses, 1952-1956
(Mean annual yields in cwt. clean coffee per acre)

Year	N ₀	N ₁	N ₂	T ₀	T ₁	T ₂	Mean	C. of V. %	Least Sig- nificant Difference	
									p = 0.05	p = 0.01
1952	0.76	0.61	1.18	0.83	0.75	0.97	0.85	332.1	2.82	3.89
1953	11.09	11.44	11.25	11.21	11.41	11.14	11.26	7.0	0.79	1.09
1954	4.40	5.09	4.87	4.51	4.72	5.12	4.78	27.2	1.29	1.78
1955	12.38	15.28	15.43	14.43	13.80	14.87	14.37	13.3	1.91	2.64
1956	4.31	4.28	5.57	4.92	5.09	4.15	4.72	31.1	1.46	2.02
1953-1956 % of N ₀	8.04 100	9.03 112	9.28 115	8.77	8.76	8.82	8.79			

No significant difference between treatments could be detected in the yields of the 1953, 1954 and 1956 crops, but a highly significant response to both levels of fertilizer was recorded in 1955. In no year was there any difference between the times of application (T₀, T₁, T₂) and level of fertilizer application (N₁, N₂).

TABLE XXI
NITROGEN V. TIME INTERACTION TABLE (a)
The effect of time of application on the coffee yield response to different rates of a nitrogenous fertilizer
(Mean annual yields in cwt. clean coffee per acre)

<i>Year</i>	<i>N₀-Nil</i>				<i>N₁ = 46 lb. N.</i>				<i>N₂ = 46 lb. N.</i>				<i>General Mean</i>	<i>Least Significant Difference</i>
	<i>T₀</i>		<i>T₁</i>		<i>Mean</i>	<i>T₀</i>	<i>T₁</i>	<i>T₂</i>	<i>Mean</i>	<i>T₀</i>	<i>T₁</i>	<i>T₂</i>		
1952 Mean	0.39	0.57	1.31		0.76	0.53	0.57	0.73	0.61	1.57	1.11	0.87	0.85	$p = 0.05$
1953 Mean	11.12	11.21	10.93		11.09	10.99	11.64	11.69	11.44	11.52	11.40	10.81	11.25	0.01
1954 Mean	4.39	4.19	4.60		4.40	4.58	4.98	5.70	5.09	4.56	4.98	5.06	4.78	
1955 Mean	13.56	10.83	12.75		12.38	15.11	14.84	15.90	15.28	14.61	15.73	15.96	15.43	
1956 Mean	3.71	4.85	4.36		4.31	4.60	4.64	3.59	4.28	6.43	5.78	4.49	4.37	
1953-1956 Mean	8.20	7.77	8.16		8.04	8.88	9.03	9.22	9.03	9.28	9.47	9.08	9.28	

TABLE XXII
NITROGEN V. TIME INTERACTION TABLE (b)
The effect of different rates of application of a nitrogenous fertilizer on the coffee yield response to different times of fertilizer application
(Mean annual yields in cwt. clean coffee per acre)

Year	T_0 - Long Rains			T_1 - Short Rains			T_2 - $\frac{1}{2}$ in each rains		Least Significant Difference	
	N_1	N_2	Mean	N_1	N_2	Mean	N_1	N_2	$p = 0.05$	$p = 0.01$
1952 Mean	0.53	1.57	1.05	0.57	1.11	0.84	0.73	0.87	4.89 3.45	6.73 4.76
1953 Mean	10.99	11.53	11.26	11.64	11.40	11.52	11.69	10.81	1.37 0.97	1.89 1.34
1954 Mean	4.58	4.56	4.57	4.98	4.98	4.98	5.70	5.06	2.24 1.58	3.09 2.18
1955 Mean	15.11	14.61	14.86	14.84	15.73	15.29	15.90	15.96	3.32 2.34	4.57 3.23
1956 Mean	4.60	6.43	5.52	4.64	5.78	5.21	3.59	4.49	2.54	3.50
1953-1956 Mean	8.88	9.28	9.08	9.03	9.47	9.25	9.22	9.08		

So far this trial has yielded little positive information, but it has reduced the likelihood that it matters in which growth period the fertilizer is applied so that single or split fertilizer applications may be put on as convenient. However, the evidence of growth measurements has suggested that for maximum growth the nitrogenous fertilizer should be applied in several small amounts spread through each rains.

References

JONES, P. A. (ed.) *Guide to the Research Laboratories and Field Trials on Jacaranda Estate*, 1956, 28.
A.R. Dept. Agric. Kenya, 1955, 2, 72.

MANURIAL TRIAL IV (NITROGEN TRIAL)

Site: Level, deep fertile soil.
 Date Planted: Before 1920.
 Spacing: 10 ft. $\times$ 10 ft.
 Shade: None.
 Pruning System: Multiple Stem.
 Trial Commenced: April, 1954.

Objects

1. To study the interaction of mulch and a nitrogenous fertilizer with particular reference to the placement of the fertilizer.
2. To test several amounts and positions of mulch.
3. To extend the range of dressings of a nitrogenous fertilizer under study on this station.

Layout

A fully factorial design for the treatments to be tested would have necessitated a $2 \times 3 \times 4$ combination of three factors, but as space for the full layout was not available all dummy treatments were omitted, thus reducing a full replicate from 24 to 18 plots. The use of this layout was only possible because data for covariance analysis was available for the previous trial on the same site. There are three "replicates" of 18 plots each of 20 trees in two rows of ten. Since the indirect replication becomes unbalanced by the reduction from the full factorial design, ten different standard errors are needed for the comparison of all treatment means. In the tables which follow the values for the Least Significant Differences must be selected with care so that the two small letters (e.g. a and b) correspond with those beside the two values to be compared.

Treatments

Nitrogenous fertilizer—	N ₀ —Nil.
Applied early in the	N ₃ —69 lb. Nitrogen:
Long Rains—April.	1954-56—3 cwt. ammonium sulphate per acre.
	1957—150 lb. urea per acre.
	N ₆ —138 lb. Nitrogen:
	1954-56—6 cwt. ammonium sulphate per acre.
	from 1957—300 lb. urea per acre.
Mulching—	M ₀ —Nil.
Applied before the	M ₁ —3 ft. per tree as a 6-ft. band of mulch laid in alternate inter-
Long Rains—March.	rows in alternate years.
	M ₂ —4½ ft. per tree as a 4½-ft. band laid in the tree rows.
	M ₃ —6 ft. per tree as a 6-ft. band of mulch in every inter-row.
Fertilizer Placement—	P ₁ —The nitrogenous fertilizer applied to the bare soil around the tree only.
	P ₂ —The nitrogenous fertilizer applied only to the mulch around the tree.

Results

For the first two years of this trial no mulch treatment produced a significant increase in coffee yield, but in 1956, as Table XXIII shows, the mulched plots produced just over 100% more clean coffee than the unmulched plots. There is no significant overall difference recorded between any of the methods of mulching, so that the application of 3½ ft. of mulch per tree has been as effective in improving the coffee yield as 6 ft. of mulch per tree.

TABLE XXIII
Summary of Results 1954-1956
(Mean annual yields in cwt. clean coffee per acre)

1954								
Lb. Nitrogen per acre per year	Mulch Treatments				Mean	Least Significant Difference		
	M ₀	M ₁	M ₂	M ₃		Between	p = 0.05	p = 0.01
N ₀ — Nil	a. 6.99	a. 7.89	a. 5.78	a. 6.75	d. 6.85	a & a b & b	2.12 1.51	2.85 2.03
N ₃ — 69	a. 6.80	b. 7.27	b. 6.28	b. 5.32	g. 6.42	a & b c & e	1.85 1.10	2.48 1.48
N ₆ — 138	a. 8.49	b. 6.62	b. 8.01	b. 5.87	g. 7.25	e & e d & g g & g	0.48 0.95 0.40	0.64 1.27 0.54
Mean C. of V. %	c. 7.43	e. 7.26	e. 6.69	e. 5.98	6.84 18.8			
1955								
N ₀ — Nil	a. 11.26	a. 10.82	a. 11.80	a. 9.61	d. 10.87	a & a b & b	3.75 2.66	5.03 3.57
N ₃ — 69	a. 13.01	b. 13.24	b. 14.94	b. 15.41	g. 14.15	a & b c & e	3.26 1.94	4.38 2.61
N ₆ — 138	a. 13.63	b. 12.73	b. 16.17	b. 14.74	g. 14.32	e & e d & g g & g	0.84 1.67 0.71	1.13 2.24 0.96
Mean C. of V. %	c. 12.63	e. 12.26	e. 14.30	e. 13.25	13.11 17.3			
1956								
N ₀ — Nil	a. 8.88	a. 17.71	a. 17.46	a. 17.29	d. 15.34	a & a b & b	3.05 2.17	4.09 2.91
N ₃ — 69	a. 7.69	b. 16.85	b. 16.83	b. 17.42	g. 14.70	a & b c & e	2.65 1.58	3.56 2.12
N ₆ — 138	a. 8.52	b. 15.61	b. 16.62	b. 16.60	g. 14.34	e & e d & g g & g	0.68 1.36 0.58	0.92 1.82 0.78
Mean C. of V. %	c. 8.36	e. 16.72	e. 16.97	e. 17.10	14.79 12.5			
1954-1956								
N ₀ — Nil	a. 9.04	a. 12.14	a. 11.68	a. 11.22	d. 11.02	a & a b & b	3.18 2.26	4.27 3.03
N ₃ — 69	a. 9.17	b. 12.45	b. 12.68	b. 12.71	g. 11.75	a & b c & e	2.77 1.65	3.72 2.21
N ₆ — 138	a. 10.21	b. 11.69	b. 13.60	b. 12.40	g. 11.97	e & e d & g g & g	0.71 1.42 0.60	0.96 1.90 0.81
Mean C. of V. %	c. 9.47	e. 12.09	e. 12.65	e. 12.11	11.58 16.7			

The yield responses to the high rate of fertilizer used in this trial have been disappointing, for only in 1955 was there a significant difference in the overall nitrogenous fertilizer means. In this year both N_3 and N_6 treatments gave yields highly significantly greater than the N_0 treatment. The mean annual figures for the three years show no advantage at all to the application of the nitrogenous fertilizer, and neither do they indicate any form of antagonism or negative interaction between the mulch and nitrogen.

TABLE XXIV
The effect of fertilizer placement on the response to nitrogen
(Mean annual yields in cwt. clean coffee per acre)

1954					
Fertilizer placement	N_3	N_6	Mean	Least Significant Difference	
				$p = 0.05$	$p = 0.01$
				Within the Table	
P_1 — Application to bare soil	6.69	7.11	6.90	0.62	0.83
P_2 — Application to mulched soil	5.89	6.55	6.22	Marginal Means	
				0.44	0.59
Mean	6.29	6.83	6.56		
1955					
P_1	15.69	14.87	15.28	Within the Table	
				1.09	1.46
P_2	13.42	14.22	13.82	Marginal Means	
				0.77	1.03
Mean	14.55	14.55	14.55		
1956					
P_1	17.46	15.48	16.47	Within the Table	
				0.88	1.19
P_2	16.60	17.07	16.84	Marginal Means	
				0.63	0.84
Mean	17.03	16.28	16.66		
1954-1956					
P_1	13.78	12.49	13.14	Within the Table	
				0.92	1.24
P_2	11.97	12.63	12.30	Marginal Means	
				0.65	0.87
Mean	12.88	12.56	12.72		

The trial has not yet answered the question of fertilizer placement clearly. The yields of 1954 and 1955 show that fertilizer application to the bare soil (P_1) was significantly better than its placement over the mulch (P_2). In 1956, however, the bare soil (P_1) treatment was not better than (P_2) and at the higher level of nitrogenous fertilizer (N_6) the best response came from the (P_2) treatment where the fertilizer was scattered on to the mulch. If this is a real effect and borne out by the results of future years, the explanation may be that the high level of fertilizer is most efficiently used when it is placed over mulch so that the the nitrogen is released to the coffee tree more steadily and over a longer period than would be the case if the fertilizer were applied directly to the bare soil.

PRUNING TRIAL I

Site: Level, deep fertile soil.
Date Planted: Before 1920.
Spacing: 10 ft. × 10 ft.
Shade: None.
Pruning System: According to treatment described below.
Trial Commenced: 1945.

Object

1. To compare four methods of pruning following the regeneration of poor single-stem coffee by stumping.

Layout

There are six randomized blocks of four 16-tree plots. In each plot the trees are arranged in four rows of four and are surrounded on all sides by a row of coffee pruned on the multiple-stem system.

Treatments

Pruning Systems:

- A. Multiple stem—allowing three heads.
- B. Single stem capped once at about 5 ft.
- C. Single stem capped three times at about 2 ft., 3½ ft. and 5 ft.
- D. Single stem—applied to two heads which are capped at 5 ft.

Results

During their first cycle the multiple-stem trees yielded significantly more than the single-stem trees, but this lead was lost in the years 1952 and 1953 when the multiple-stem trees produced little more than three hundredweight of clean coffee in the two years of conversion. In these two years nearby multiple-stem trees, in the process of conversion from one pruning cycle to another, yielded between eight and ten hundredweight of clean coffee per acre.

TABLE XXV
Summary of Results 1946-1956
 (Mean annual yields in cwt. clean coffee per acre.)

Year	A Multiple Stem 3 heads	B Single Stem Capped Once	C Single Stem Capped 3 times	D Single Stem 2 stems	Mean	C. of V. %	Least Significant Difference	
							p = 0.05	p = 0.01
1946	2.31	1.59	0.58	2.09	1.64	18.7	0.38	0.52
1947	13.55	6.15	5.82	10.01	8.88	13.1	1.43	1.98
1948	2.05	0.98	1.43	0.72	1.30	52.6	0.73	1.01
1949	5.79	3.86	3.57	3.09	4.08	20.1	1.01	1.39
1950	1.25	2.99	1.60	1.50	1.84	11.9	1.49	2.06
1951	15.17	15.39	16.40	17.45	16.23	9.3	1.85	2.56
Multiple stem 1st cycle	6.69	5.24	4.90	5.81	5.66	7.7	0.60	0.80
1952	0.09	3.16	2.04	1.35	1.66	76.0	1.55	2.14
1953	3.04	21.06	21.35	22.13	11.56	8.7	1.80	2.50
1954	13.57	1.04	0.68	0.80	4.02	24.0	1.18	1.64
1955	8.24	19.83	18.85	19.32	16.56	11.9	2.43	3.36
1956	8.54	0.05	0.01	0.04	2.16	80.7		
1952-56	6.70	9.03	8.59	8.73	8.26			
1946-56	6.69	6.96	6.58	7.14	6.84		0.19	0.26

In the second multiple-stem cycle, which has run since 1952, the single-stem systems have outyielded the multiple-stem system, so that in the 11-year means in Table XXV it may be seen that the single-stem systems B and D have yielded significantly more than the multiple-stem system A.

TABLE XXVI
Percentage of clean coffee retained by an "A" screen

Year	A Multiple Stem 3 heads	B Single Stem Capped Once	C Single Stem Capped 3 times	D Single Stem 2 stems	Mean % A	C. of V. %	Least Significant Difference	
							p = 0.05	p = 0.01
1951	25.1	36.8	37.2	37.1	34.1			
1952	22.6	27.2	24.1	31.3	26.3			
1953	16.1	16.1	15.3	13.2	15.2			
1954	33.1	34.4	35.8	37.6	35.2			
1955	42.4	22.2	22.8	23.7	27.8			
1956	53.5	20.2	2.8	36.9	28.4			
Mean	32.1	26.1	23.0	30.0	27.8	6.2	2.1	2.9

Since 1951 the single-stem trees have developed a very marked tendency to bear heavily in alternate years. Such crops are of very low quality and are usually inferior to those borne on multiple-stem trees in the same year which carry their crops to ripeness without undue strain. A measure of this strain is given by the percentage by weight of clean coffee beans retained by an "A" grade screen. Table XXVI shows that in this respect the multiple-stem system is better than all the single-stem systems, and of the single-stem systems the single 2-stem is clearly the best. A>*D>**B>**C.

References

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THE REDUCTION OF LEAF FALL BY SPRAYING ALSO KNOWN AS "TONIC" SPRAYING

During the past 20 years a large number of trials have been carried out which have established that timely spraying with a fungicide—usually a copper formulation—can lead to substantial yield increases in the year following spraying. This effect is apparently the result of increased length of leaf life and the consequent improvement in the overall nutrient economy of the coffee tree. Although this information is widely known among Kenya coffee growers, many of whom apply a copper spray annually as a matter of routine, a number of important aspects of the subject are under active investigation. These may be classified as follows:—

- The mode of action of the fungicide spray and the identification and study of the fungus or fungi believed to be responsible for premature leaf fall.
- The relative efficiency of various copper and copper-free fungicides.
- The optimum concentration of fungicide to be used.
- The optimum volume of spray to be applied to each tree.
- The most effective sprayers and the relation of headings (c) and (d) to these machines.
- The best time of spraying, particularly in areas far removed from former trials.

The fund of knowledge on all these aspects is being extended by the trials reported below, which are situated on or run from the Coffee Research Station, Ruiru.

Note: All copper concentrations are given in terms of the number of pounds (lb.) of a 50% copper formulation in each 100 gallons of spray fluid. In all the trials described here, "Perenox" has been used as the copper fungicide, unless otherwise stated, but it is considered that the results are applicable to any 50% copper fungicide.

COPPER AND NON-COPPER SPRAY TRIAL: COFFEE RESEARCH STATION, RUIRU

<i>Site:</i>	Level, fertile red soil.
<i>Date Planted:</i>	Before 1920.
<i>Spacing:</i>	10 ft. × 10 ft.
<i>Shade:</i>	None.
<i>Pruning System:</i>	Single Stem.
<i>Trial Commenced:</i>	1954.

Object

To determine whether copper fungicide sprays reduce leaf fall through their fungicidal properties alone or if there is also an effect attributable to their copper content.

Layout

Four randomized blocks of six, 25-tree, single-row plots.

Treatments

(1) No treatment to reduce leaf fall.

1P. 1 pint per tree of a spray containing 6.8 lb. of 50% copper formulation ("Perenox") per 100 galls. of water. Applied in the second half of May (Late Long Rains).

2P. The above treatment applied in the second half of May and late in October (Early Short Rains).

D. Dusting with a 10% copper formulation ("Cuprosana").

1954—approx. 40 grammes/tree.

1955—approx. 60 grammes/tree.

F. 2 pints per tree of a spray containing 3 lb. of a non-copper organic fungicide (thiram—"Fernide") per 100 galls. of water applied in the early, middle and late part of the Long Rains.

H. 3 pints per tree of a spray containing 2 per cent alpha-naphthalene acetic acid ("Anapal").

1954—20 p.p.m. active ingredient.

1955—30 p.p.m. active ingredient + Agral L.N.

Method of Application

Spraying.

All the treatments were applied by hand with a knapsack pneumatic sprayer (Eclipse Warley) at a pressure of 60 p.s.i.

Dusting.

The dust was applied with a "Whirlwind" hand-operated machine delivering approximately 40 lb./acre (1954) or 60 lb./acre (1955).

Results

Measures of leaf fall.

Leaf fall has been recorded regularly since July, 1954. Shallow saucers were cleared around the first five trees in each plot. The number of leaves in the saucers were counted at the end of each week.

In 1954 heavy leaf fall was recorded from trees in the control plots between June and September, but it was not marked during the rest of the year. Leaf fall on the plots treated with "Perenox" and "Fernide" was considerably lower, "Fernide" producing slightly better control than "Perenox". Dusting had little effect until August but from then until the end of the year this treatment produced an appreciable reduction in leaf fall, though less than did the fungicidal sprays. The hormone treatment led to no measurable reduction in leaf fall.

In 1955 on the unsprayed plots the main period of leaf fall was between August and November, but there was a considerable loss of leaf in January and December. In the first half of the year the plots which had received two lots of "Perenox" in 1954 lost less leaf than any other of the treatments. In the second half of the year the "Fernide" treatment gave the best control of leaf fall. The trees on the dusted and hormone-sprayed plots lost as many leaves and at the same seasons as did the trees on the control plots.

In 1956 heavy leaf fall occurred between July and September and again in November. All treatments produced less leaf fall than the controls, the reduction being most marked with the "Fernide" treatments. The hormone spraying appeared to have produced some control of leaf fall but it was less effective than the fungicide sprays and dusts, there being no marked differences between these later, though the treatment with a second cuprous oxide spray at the beginning of the Short Rains gave less leaf fall between January and March than did the single spray in May.

Yields of clean coffee.

The yield of coffee was not recorded in 1954 since responses are not normally found in the first year of spray trials of this sort.

In 1955 the whole trial yielded at a high level (mean yield 16.98 cwt. clean coffee/acre) and this resulted in an extremely low level of cropping in 1956 (mean yield 0.51 cwt. clean coffee/acre).

TABLE XXVII
Summary of Yields 1955-1956
(Mean annual yield in cwt. clean coffee per acre)

<i>Treatments</i>	<i>Yield</i>	<i>% of Control</i>
Control —	6.70	100
"Perenox" — 1 spraying	9.43	141
"Perenox" — 2 sprayings	9.27	138
"Fernide" — 3 sprayings	9.78	146
"Cuprosana" dust	9.15	137
"Anapal" hormone spray	8.17	122
<i>Least Significant Differences:</i>		
p = 0.05	1.08	
p = 0.01	1.51	
p = 0.001	2.07	

In Table XXVII the mean annual yields for the two years 1955 and 1956 are presented. It is clear that each treatment has led to a worthwhile increase in yield of clean coffee, but while there is no significant difference between the various fungicidal treatments the hormone treatment is significantly inferior to the "Perenox" treatments and highly significantly inferior to the "Fernide" treatment.

MACHINE SPRAY TRIAL I: COFFEE RESEARCH STATION, RUIRU

Site: Deep, level fertile red soil.
Date Planted: Before 1920.
Spacing: 10 ft. × 10 ft.
Shade: None.
Pruning System: Single Stem.
Trial Commenced: 1954.

Object

1. To compare two types of tractor-drawn sprayers when used to apply spray to reduce leaf fall.
2. To compare two rates and two concentrations of a copper spray to reduce leaf fall.

Layout

Four randomized blocks of six, 23-tree, single-row plots.

Treatments

- (1) No spray.
- 2L1. 30 gallons of spray per acre containing 6.8 lb. of a 50% copper formulation per 100 gallons spray fluid; applied with a Ransome's "Agro Airblast" sprayer

- 2L2. 60 gallons of spray per acre containing 6.8 lb. of a 50% copper formulation per 100 gallons of spray fluid; applied with a Ransome's "Agro Airblast" sprayer.
- 4L1. 30 gallons of spray per acre containing 13.6 lb. of a 50% copper formulation per 100 gallons spray fluid applied with a Ransome's "Agro Airblast" sprayer.
- 4L2. 60 gallons of spray per acre containing 13.6 lb. of a 50% copper formulation per 100 gallons spray fluid applied with a Ransome's "Agro Airblast" sprayer.
- 2HL. 120 gallons of spray per acre containing 6.8 lb. of a 50% copper formulation per 100 gallons of spray fluid applied with a Drake and Fletcher Quadrex "S" sprayer.

Results

TABLE XXVIII
Yield summary 1955-1956
(Mean annual yields in cwt. clean coffee per acre)

Lb. of 50% copper formulation/ 100 galls.	Galls. per acre	1955	1956	Mean	%
0	Nil	3.03	14.84	8.94	100
6.8	"Agro" 30	10.00	11.73	10.87	122
6.8	"Agro" 60	10.28	10.31	10.30	115
13.6	"Agro" 30	10.49	11.92	11.21	125
13.6	"Agro" 60	8.41	14.75	11.58	130
6.8	"Quadrex" 120	10.46	12.67	11.57	129
Mean annual yield		8.77	12.70		
C. of V. %		29.7	30.0		
Least Significant Difference					
p = 0.05		3.93	5.74		
p = 0.01		5.44	7.94		

Yields were not recorded in the first year of spraying as it has been found that no yield response is apparent until the first year after treatment. Table XXVIII shows that, while all the sprayed crops yielded about three times the crop of the unsprayed plots in 1955, there was no significant difference between treatments in 1956, so that in the two-year period the best spray treatment has led to a 30% increase in yield over the unsprayed plots.

TABLE XXIX
Concentration x Volume Interaction Table (Mean Annual yields)

Lb. of 50% copper formulation/ 100 galls.	Gallons per acre				Mean	%
	Nil	30	60	120		
Nil	8.94	—	—	—	8.94	100
6.8 lb.	—	10.87	10.30	11.57	10.91	122
13.6 lb.	—	11.21	11.58	—	11.40	128
Mean	8.94	11.04	10.94	11.57		
% of "Nil" treatment	100	124	122	129		

In Table XXX the mean annual yields for the two crops are tabulated to show that there appears to be a trend for the higher rates and concentrations to be superior to the lower rates and concentrations; however, this has not been tested statistically.

MACHINE SPRAY TRIAL II: COFFEE RESEARCH STATION, RUIRU

<i>Site:</i>	A gentle slope of fertile red soil.
<i>Dated Planted:</i>	Before 1920.
<i>Spacing:</i>	10 ft. × 10 ft.
<i>Shade:</i>	None.
<i>Pruning System:</i>	Multiple Stem.
<i>Trial Commenced:</i>	1956.

Object

1. To compare a tractor-mounted "Micron" very low volume airblast sprayer with an "Agro Airblast" sprayer.
2. To determine if higher concentrations of copper are necessary when the spray volume per acre is considerably reduced.

Layout

Four randomized blocks of five 16-tree, single-row plots.

Treatments

- A. 60 gallons of spray per acre containing 6.8 lb. of a 50% copper formulation per 100 gallons spray fluid applied with a Ransome's "Agro Airblast" sprayer.
- B. 10 gallons of spray per acre containing 6.8 lb. of a 50% copper formulation per 100 gallons spray fluid applied with a "Micron" sprayer.
- C. 10 gallons of spray per acre containing 13.6 lb. of a 50% copper formulation per 100 gallons spray fluid applied with a "Micron" sprayer.
- D. 10 gallons of spray per acre containing 34.0 lb. of a 50% copper formulation per 100 gallons spray fluid applied with a "Micron" sprayer.
- E. No spray.

Results

No yield records were made in 1956 because it has been found that the first response in crop occurs in the year following the initial spraying.

Leaf fall counts were made each week from the initiation of the trial on May 7, 1956, until December 17, 1956. Earth "basins" were swept clean under five trees selected at random from the 16 trees of each plot, and for the purposes of statistical analysis the weekly plot totals were used, thus the leaf fall was recorded from 20 trees of each treatment each week for seven months.

An inspection of the weekly leaf fall counts made it clear that the period May 7, 1956—December 17, 1956, could be subdivided into three parts as follows:—

Sub-period i.	7/5/56-26/6/56:	Increasing rate of leaf fall.
Sub-period ii.	2/7/56-20/8/56:	Maximum rate of leaf fall.
Sub-period iii.	27/8/56-17/12/56:	Decreasing rate of leaf fall.

In Table XXX the total leaf fall for the 20 trees sampled from each treatment is shown for each of these sub-periods.

TABLE XXX
Leaf fall per 20 trees during the period May 7, 1956, to December 17, 1956

Treatment	Lb. of 50% copper formula- tion/100 galls.	Galls. per acre	Type of Sprayer	Sub- period i	Sub- period ii	Sub- period iii	Total leaf fall	Mean No. leaves lost per tree
A	6.8	60	Agro	7,526	29,794	15,897	53,217	2,661
B	6.8	10	Micron	5,973	26,177	14,638	46,788	2,340
C	13.6	10	Micron	7,702	30,365	15,298	53,365	2,668
D	34.0	10	Micron	7,613	29,471	15,812	52,896	2,645
E	Nil	—	—	7,636	35,222	18,583	61,441	3,072
Least Significant Difference								
p = 0.05				705	1,760		7,430	372
p = 0.01				972	2,375		10,460	523
p = 0.001				1,335	3,158		14,782	739

In the first sub-period only the B treatment reduced the leaf fall significantly and this advantage was increased throughout the whole seven months. During the season of maximum leaf fall, sub-period (ii), all the sprayed trees lost very highly significantly ($p=0.001$) less leaves than the unsprayed trees and while there was no significant difference between treatments A, C and D, yet the B treatment was highly significantly ($p=0.001$) more effective in reducing leaf fall than any other spray treatment. In the final sub-period, when the rate of leaf fall decreased rapidly, there was little difference between the treatments. Thus in the seven-month aggregate the treatment most effective in reducing leaf fall was the "Micron" Sprayer applying 10 gallons per spray per acre of the standard strength of 6.8 lb. of the 50% copper formulation in 100 gallons of spray fluid. This treatment was very significantly ($p=0.01$) better than no spray while the other three spray treatments led to a significant ($p=0.05$) reduction in leaf fall. There was no overall significant difference between the four spray treatments.

SOLAI SPRAY TRIAL: MILMET ESTATE, SOLAI

Site: Gentle slope; fertile soil.
Date Planted: Unknown.
Spacing: 10 ft. $\times$ 10 ft.
Shade: None.
Pruning System: Multiple Stem.
Trial Commenced: May, 1951.

Objects

1. To determine the best time to apply a copper spray to reduce leaf fall in the Solai area.
2. To compare the effect on the yield of coffee of two rates of copper per tree.
3. To compare the effect on the yield of coffee of two dilutions of copper spray.

Layout

Two replications of a $4 \times 2 \times 2$ factorial design with 20-tree, single-row plots. The $T \times C \times D$ interaction is confounded between pairs of blocks in each replication.

Treatments

Time of spraying:
 T_0 No spray.
 T_1 Early spray—May.
 T_2 Middle spray—July.
 T_3 Late spray—September.

Copper rate per tree:
 C_0 1.928 gm. of a 50% copper fungicide.
 C_1 3.855 gm. of a 50% copper fungicide.

Dilution of copper fungicide—quantity of spray/tree:

D ₀	1 pint per tree.
D ₁	3 pints per tree.

The factorial combination of C and D gives a range of concentrations increasing at the ratio of 1 : 2 : 3 : 6.

Application of Treatments

For various practical reasons spray treatments were not always applied at the correct time. The actual dates of spraying are shown in Table XXXI.

TABLE XXXI

Treatment	1951	1952	1953	1954	1955
T ₁ (May)	22/5	28/5	Sept.	28/5	27/5
T ₂ (July)	17/7	29/7 Rep. I 5/8 Rep. II	Sept.	30/7	29/7
T ₃ (September)	25/9	NIL	Sept.	28/9	21/9

Results

In the mean annual yields for the five crops the most marked response in this trial, as in the similar one at Kitale, has been to the time of spraying. Copper sprays applied in May, July or September have all led to a highly significant increase in the yield of clean coffee. The May (T₁) spray has been highly significantly more effective than those applied later in the year (T₂ and T₃), but as Table XXXII shows this is largely the result of the crop responses in the 1955/56 crop season, for over the previous four crop seasons the September (T₃) spray had been as effective as that applied in May (T₁) though the July (T₂) spray has been less effective than the May (T₁) spray in four out of the five crops.

TABLE XXXII
Summary of yields 1951/52—1955/56
(Mean annual yields in cwt. clean coffee per acre)

Time of Spraying	1951/52	1952/53	1953/54	1954/55	1955/56	Mean Annual Yield
T ₀ No spray	12.1	3.1	13.7	5.1	13.6	9.5
T ₁ May	12.1	8.3	11.1	7.6	16.5	11.1
T ₂ July	11.4	5.8	14.0	5.3	15.6	10.4
T ₃ September	12.5	8.9	9.9	7.7	12.1	10.2
Concen- tration* Pints/ Tree						
C ₀ D ₁ 3.4 3	12.4	5.4	13.9	5.2	14.6	10.3
C ₁ D ₁ 6.8 3	11.9	6.4	11.3	6.9	14.2	10.1
C ₀ D ₀ 3.4 1	11.8	6.6	11.3	7.2	13.8	10.1
C ₁ D ₀ 6.8 1	11.9	7.7	12.2	6.5	15.2	10.7
Mean	12.0	6.5	12.2	6.4	14.5	10.3
Coefficient of Variation %	10.1	29.1	15.3	19.5	12.8	2.7
Least Significant Difference						
p = 0.05	1.3	2.1	2.0	1.3	1.4	0.3
p = 0.01	1.9	2.9	2.8	1.9	2.0	0.4

* lb. of a 50% copper formulation in 100 galls. of spray fluid.

The analysis of the clean coffee yields for the totals of the five crops revealed a number of statistically significant interactions between the time of spraying (T), the copper rate per tree (C) and the dilution of the fungicidal spray (D). The levels of significance of these interactions were as follows:—

T × C	.	.	.	.	p = 0.001
T × D	.	.	.	.	p = 0.05
C × D	.	.	.	.	p = 0.01
T × C × D	.	.	.	.	p = 0.05

TABLE XXXIII
Time × Copper Rate × Dilution Interaction Table
(Mean Annual Yields 1951/52—1955/56)

Time $\times$ Copper	Dilution					T $\times$ C Mean
T ₁ May Spray Copper/Tree C ₀ C ₁	Control — No Spray					d. 9.5 b. 10.6 b. 11.7
Mean (T $\times$ D)	d. 9.5 b. 11.4 b. 10.9					10.6
T ₂ July Spray Copper/Tree C ₀ C ₁	Control — No Spray					d. 9.5 b. 10.3 b. 10.6
Mean (T $\times$ D)	d. 9.5 b. 10.7 b. 10.2					10.1
T ₃ September Spray Copper/Tree C ₀ C ₁	Control — No Spray					d. 9.5 b. 10.5 b. 10.0
Mean (T $\times$ D)	d. 9.5 b. 10.1 b. 10.4					10.0
(T ₁ + T ₂ + T ₃) $\div$ 3 Copper/Tree C ₀ C ₁	Control — No Spray					d. 9.5 e. 10.5 e. 10.7
Mean (T $\times$ D)	d. 9.5 e. 10.7 e. 10.5					10.2
Least Significant Differences between	a & a	b & b a & d	b & d c & c	c & d d & e	e & e	
p = 0.05	0.6	0.5	0.4	0.3	0.2	
p = 0.01	0.8	0.6	0.5	0.4	0.3	

The final column [Time × Copper Rate (T × C) interaction] of Table XXXIII shows clearly the complete reversal in the response to the two rates of copper (C₀ and C₁) over the three times of spraying. When the spray was applied in May (T₁) C₁ was greater than C₀ (at p = 0.01); with the July spray there was no significant difference between the two rates of copper per tree but when the spray was applied in September C₀ was greater than C₁ (at p = 0.05).

Time × Dilution (T × D) Interaction:

There is also evidence of a reversal with time in the yield response to the two dilutions of spray. With the May or July (T₁ or T₂) sprays D₀ was greater than D₁ (at p = 0.05) but when the spray was applied in September there was an indication that D₁ was greater than D₀ though this difference did not reach statistical significance.

Copper Rate × Dilution (C × D) Interaction:

From the bottom section of Table XXXIII it may be seen that there has been a reversal in yield response at the two levels of C or D. At D₀ C₁ is greater than C₀ (at p = 0.01) while at D₁ the reverse is true though there is not a statistically significant difference. Similarly at C₁ D₀ is greater than D₁ (at p = 0.01) but at C₀ D₁ is slightly though not significantly greater than D₀.

Time × Copper Rate × Dilution (T × C × D) Interaction.

This second order interaction reaches statistical significance because with the May or July (T_1 or T_2) spray the C_1D_0 combination has produced a yield greater than any other treatment combination (at $p = 0.01$) but with the September spray the C_0D_1 treatment combination was the most successful. (Greater than C_1D_0 or C_1D_1 at $p = 0.01$ and greater than C_0D_0 at $p = 0.05$.)

Conclusions

1. Under conditions at Solai the copper spraying to reduce leaf fall has been successful in increasing the yield of clean coffee per acre.
2. May appears to be the best time at which to apply the copper spray to reduce leaf fall.
3. When spraying in May the best spray composition has been 6.8 lb. of a 50% copper formulation in 100 gallons of water when this has been applied at the rate of 1 pint per tree.

KITALE SPRAY TRIAL: KITALE COFFEE RESEARCH SUB-STATION

Site:	Level sandy loam; Basement Complex.
Date Planted:	1938.
Spacing:	Replications I and II: 9 ft. × 9 ft. Replication III: 10 ft. × 10 ft.
Shade:	Replications I and II: <i>Ficus gnapholocarpa</i> and <i>Calpurnia aurea</i> ; Replication III: <i>Ficus verucocarpa</i> .
Pruning System:	Multiple Stem.
Trial Commenced:	1952.

Objects

1. To determine the best time to apply an anti-leaf-fall copper spray in the Trans Nzoia area.
2. To compare the effect on the yield of coffee of two rates of copper per tree.
3. To compare the effect on the yield of coffee of two dilutions of copper spray.

Layout

Three replications of a $4 \times 2 \times 2$ factorial design with 15-tree, single-row plots. The $T \times C \times D$ interaction is confounded between pairs of blocks in each replication.

Treatments

Time of spraying:

T_0	No spray.
T_1	Early spray—mid May.
T_2	Middle spray—mid June.
T_3	Late spray—late August.

Copper rate per tree:

C_0	1.928 gm. of a 50% copper fungicide.
C_1	3.855 gm. of a 50% copper fungicide.

Dilution of copper fungicide: quantity of spray per tree.

D_0	1 pint per tree.
D_1	3 pints per tree.

The factorial combination of C and D gives a range of concentrations increasing in the ratio of 1 : 2 : 3 : 6.

Results

TABLE XXXIV
Summary of yields 1952-1956
(Mean annual yields in cwt. clean coffee per acre)

(Yields have been converted from cherry to clean coffee by dividing the cherry weight by 6)

Time of Spraying	1952	1953	1954	1955	1956	1952-1956
T ₀ — No spray	7.49	6.38	8.22	6.87	5.21	6.83
T ₁ — May	7.53	8.27	10.40	10.38	6.65	8.65
T ₂ — June	7.77	7.14	10.48	8.46	7.73	8.32
T ₃ — August	7.79	6.30	11.68	5.99	8.00	7.95
Least Significant Difference						
p = 0.05	1.02	0.91	2.21	1.61	0.92	0.65
p = 0.01	1.37	1.22	2.97	2.17	1.24	0.88
C. of V. %	15.85	15.39	26.33	24.20	15.85	9.88

Only in the case of the spray timing treatments have consistent results been obtained since the first "response" year of 1953. The mean annual figures in Table XXXIV show that the highest yield has followed the May spraying (T₁) and the June (T₂) and August (T₃) treatments have produced less than (T₁), but all sprayed treatments have yielded very significantly more than the control treatment, and of the spraying times the May spray has led to significantly more crop than the August treatment, the June treatment taking an intermediate position.

TABLE XXXV
Spray constitution x Time interaction table
(Total yields for 1952-1956 in cwt. clean coffee per acre)

Treatment	Concentration *	Pints of spray per tree	T ₀ No spray	T ₁ May	T ₂ June	T ₃ August	Means
C ₀ D ₁	3.4	3	36.55	40.31	38.87	38.69	38.61
C ₁ D ₁	6.8	3	32.08	43.22	42.72	43.22	40.31
C ₀ D ₀	3.4	1	30.04	43.79	43.99	39.99	39.45
C ₁ D ₀	6.8	1	38.01	45.58	40.72	37.13	40.36
Means			34.17	43.23	41.58	39.76	
Least Significant Difference between marginal means within the table			p = 0.05 3.28 6.56	p = 0.01 4.42 8.84	p = 0.001 5.87 11.74		

* lb. of a 50% copper formulation in 100 gallons of spray fluid.

Table XXXV shows that there has been no clear difference between the various concentrations and quantities of copper spray employed, though after the May spray (T₁), which has been the most effective, the highest yields have been recorded from the plots sprayed at the C₁D₀ level in four out of the five years. While this is not a statistically significant difference, it is of interest since this concentration of 6.8 lb. of a 50% copper formulation per 100 gallons of spray has been the most effective in other trials and is the strength recommended to farmers for the anti-leaf-fall spray.

MAKUYU SPRAY TRIAL: MAKUYU COFFEE RESEARCH SUB-STATION ON NORTH KITITO ESTATE

Site: Level red soil.
Date Planted: 1938.
Spacing: 9 ft. x 9 ft.
Shade: None.
Pruning System: Multiple Stem.
Trial Commenced: May, 1954.

Object

To discover the best time to apply the anti-leaf-fall spray under Makuyu conditions.

Layout

Four randomized blocks of four, 12-tree, single-row plots.

Treatments

T ₀	No spray.
T ₁	1 pint per tree of a spray containing 6.8 lb. of a 50% copper formulation per 100 gallons of spray applied by hand early in the Long Rains—April.
T ₂	1 pint per tree of a spray containing 6.8 lb. of a 50% copper formulation per 100 gallons of spray applied by hand late in the Long Rains—May/June.
T ₃	1 pint per tree of a spray containing 6.8 of a 50% copper formulation per 100 gallons of spray applied early in the Short Rains—November.

Results

The crop was first recorded in 1955 when the yields of the sprayed plots were greater than the unsprayed ones, but only the T₂ or Late Long Rains spray gave an increase which was statistically significant. There was no statistical difference between yields in 1956, but from Table XXXVI it may be seen that in the two-year mean yields both the Long Rains sprays have been very significantly better than the Control treatment and the Late Long Rains spray has been significantly more effective than the Short Rains treatment.

TABLE XXXVI

Summary of Results 1955-1956 in cwt. clean coffee per acre

Treatment 6.8 lb. of 50% copper formulation in 100 galls. 1 pint per tree		1955		1956		1955 + 1956	
No spray	T ₀	4.56	100%	6.25	100%	10.81	100%
Early Long Rains	T ₁	6.93	152%	7.10	114%	14.03	130%
Late Long Rains	T ₂	7.83	172%	6.99	112%	14.82	137%
Early Short Rains	T ₃	5.43	119%	6.86	110%	12.29	114%
Least Significant Difference							
		p = 0.05		1.54		2.10	
		p = 0.01		—		3.02	
		p = 0.001		—		4.45	
C. of V. %		24.7		14.2		10.1	

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VARIETY TRIALS

In 1950 a coffee variety trial programme was laid down to cover the whole Colony so that information might be collected on the performance of the improved coffee selections under widely varying ecological conditions typical of Kenya. This scheme is closely integrated with the expansion of African coffee-growing, but although a large number of trials are situated in the Reserves the information obtained will often be applicable to neighbouring European Areas. The location of the various trials may be summarized as follows:—

Variety Trials in European Areas.

- i. Trial I, at the Coffee Research Station, Ruiru, planted in 1950.
- ii. Trial II, at the Coffee Research Station, Ruiru, planted in 1951.
- iii. Makuyu Coffee Research Sub-station.
6 varieties in 5 randomized blocks planted in 1953.
- iv & v. Kentmere Estate, Upper Kiambu.
Trial I. 16 varieties in a 4×4 balanced lattice planted in 1954.
Trial II. 9 varieties in a 3×3 balanced lattice planted in 1954.
- vi. Kitale Coffee Research Sub-station.
16 varieties in a 4×4 balanced lattice planted in 1954.
- vii. Scott Agricultural Laboratories, Kabete.
9 varieties in 6 randomized blocks planted in 1956.

Variety Trials in African Areas.

Two types of trials have been laid down in these Areas. The first is a major yield recorded trial with individual plots of between six and ten trees, and the second, which is far more numerous, consists of single-tree plots arranged in 5×5 , 6×6 or 7×7 Latin Squares. These latter trials are used to extend the detailed large trials to nearby areas of varying ecology.

(a) Large trials having plots of between 6 to 10 trees:

- i. South Nyanza—Kisii; 7×7 Latin Square planted in 1950.
- ii. Teita—Wundanyi; 6×6 Latin Square planted in 1951.
- iii. Nyeri Farm; 5 varieties in 6 randomized blocks planted in 1952.
- iv. Meru—Meru; 5×5 Latin Square planted in 1951.
- v. Chogoria 5×5 Latin Square planted in 1951.
- vi. Embu—Embu Investigation Centre; 5×5 Latin Square planted in 1951.
- vii. Kerugoya; 5×5 Latin Square planted in 1951.

viii & ix. North Nyanza—Shikusa; two 7×7 Latin Squares, one of which includes cultural treatments, planted in 1954.

(b) Miniature trials having single-tree plots:

Nyanza Province	.	.	.	44 trials
Central Province	.	.	.	29 trials
Southern Province	.	.	.	25 trials
Rift Valley Province	.	.	.	14 trials
Coast Province	.	.	.	2 trials

VARIETY TRIAL I: COFFEE RESEARCH STATION, RUIRU

Site:	Level deep soil.
Date Planted:	1950.
Spacing:	9 ft. $\times$ 9 ft.
Shade:	None.
Pruning System:	Multiple Stem—with two heads in the first cycle and three heads thereafter.
Trial Commenced:	1950.

Object

To compare 16 varieties selected at the Scott Agricultural Laboratories, Kabete (SL.), and Kitamaiyu Estate, Ruiru (KIT.).

Layout

A balanced incomplete block design with 20 blocks of 4 plots each being a single row of 20 trees.

Management

For two and a half years from planting in the field the trees were kept free of crop, but thereafter no crop reduction has been carried out beyond a routine and uniform pruning immediately after each crop has been picked.

Results

The yields from the four crops harvested so far are shown in Table XXXVII, from which it may be seen that the varieties SL.30 and SL.14 have yielded very highly significantly more than all those listed below KIT.27, and SL.28 has yielded significantly more than all varieties below KIT.27. Although it is early to reach any firm conclusions it is evident that on the whole the Scott Laboratory selections are superior to those from Kitamaiyu Estate and that the first three varieties in Table A are superior to the rest. Unfortunately SL.30 appears particularly susceptible to Leaf Rust (*Hemileia vastatrix*) and it was observed at Kitale that SL.14 was very susceptible to Coffee Berry Disease (*Colletotrichum coffeanum*). However, it is a variety which has done very well in the lower and drier of Kenya's coffee areas, to which it is hoped Coffee Berry Disease will not spread.

Seed from the selection SL.28 has been issued in great quantities from this Station since 1947. (See Table LXXII on page 105.)

TABLE XXXVII
1953-1956
(Yields in cwt. clean coffee per acre)

Variety	1953	1954	1955	1956	1953-1956	Mean annual yield
SL.30	5.26	14.19	6.58	13.31	39.34	9.84
SL.14	4.81	13.58	9.41	11.51	39.31	9.83
SL.28	5.82	12.45	12.91	6.35	37.53	9.38
SL.19	5.89	11.63	13.42	5.21	36.15	9.04
KIT.27	6.77	10.90	7.95	8.58	34.20	8.55
KIT.85	4.71	10.24	6.51	11.71	33.17	8.29
KIT.64	4.27	11.83	4.08	12.91	33.09	8.27
SL.17	2.28	10.97	8.27	11.36	32.88	8.22
KIT.107	5.11	9.15	7.64	10.24	32.14	8.04
SL.1	5.74	9.25	9.46	7.65	32.10	8.03
KIT.106	3.95	10.61	5.24	12.17	31.97	7.99
KIT.37	5.26	9.39	7.60	9.03	31.28	7.82
KIT.251	5.61	8.77	9.35	7.51	31.24	7.81
KIT.13	4.78	9.93	8.04	7.90	30.65	7.66
KIT.145	3.47	9.58	6.39	10.82	30.26	7.57
KIT.109	3.40	10.81	4.83	10.88	29.92	7.48
Least Significant Difference						
p = 0.05	1.20	0.70	0.72	2.80	4.21	1.05
p = 0.01	1.59	0.93	0.95	3.71	5.58	1.40
C. of V. %	18.6	4.8	6.7	21.2	9.4	

VARIETY TRIAL II: COFFEE RESEARCH STATION, RUIRU

Site: Level, deep fertile soil.
Date Planted: 1951.
Spacing: 9 ft. × 9 ft.
Shade: None.
Pruning System: Multiple Stem with two heads in the first cycle and three heads thereafter.
Trial Commenced: 1951.

Object

To compare 21 selections made at the Scott Agricultural Laboratories (SL.), Lyamungu Coffee Research Station, Tanganyika (N. and KP.), Morini Estate (M.), Legetet Estate (K.) and collected from Ethiopia (Dalle Mixed and Dilla and Alghe).

Management

This trial was planted one year after Variety Trial I and the general management has been the same so that the first crop was picked in 1954.

Results

Since only three crops have been harvested so far, little weight can be attributed to the yield results to date. As Table XXXVIII shows, SL.34 and N.218 have considerably outyielded most other selections in this trial; however, the performance of K.7 is interesting as it is the only one of the selections showing resistance to Leaf Rust (*Hemileia vastatrix*) as well as a high yield such as was recorded in 1956 when it produced more clean coffee per acre than any of the other selections.

The final column of Table XXXVIII shows the number of trees out of 100 of each selection attacked by Leaf Rust during the course of a severe outbreak in August, 1956. It is evident that with the exception of K.7 most of the selections showing any degree of resistance to Leaf Rust are low on the list of yield for the three years. A closer inspection of the table reveals that most of these varieties produced very low yields in 1954 but quite tolerable crops in 1955 and 1956.

TABLE XXXVIII
1954-1956
(Yields in cwt. clean coffee per acre)

Variety	1954	1955	1956	3 years total	Mean yield/year	Number of trees out of 100 showing Leaf Rust in August, 1956
SL.34	12.90	10.30	11.85	35.14	11.71	97
N.218	11.66	12.16	11.20	35.02	11.67	100
Dalle Mixed	12.25	11.17	9.58	33.00	11.00	98
M.83	12.04	6.34	11.36	29.94	9.98	98
M.6	10.27	8.00	11.14	29.41	9.80	98
K.7	8.54	7.25	12.45	28.24	9.41	21
SL.9	8.79	9.90	9.53	28.22	9.41	98
SL.2	9.72	12.03	6.31	28.06	9.35	99
SL.10	8.39	10.24	8.70	27.33	9.11	99
Mocha	9.40	7.32	9.99	26.71	8.90	100
N.100	10.45	5.32	10.44	26.21	8.74	100
SL.28	7.23	8.72	9.98	25.93	8.64	99
M.65	7.83	8.51	9.32	25.66	8.55	98
Kenya Selected	5.52	10.44	8.72	24.68	8.23	100
Series L	5.14	10.48	8.92	24.64	8.18	100
SL.18	4.74	8.84	9.37	22.95	7.65	98
Kents	5.29	7.38	10.14	22.81	7.60	35
KP.532	5.11	7.82	8.37	21.30	7.10	14
Dilla and Alghe	6.89	7.30	6.84	21.03	7.01	39
M.48	5.28	6.57	8.27	20.12	6.71	100
SL.6	2.21	8.42	6.17	16.80	5.60	3
Least Significant Difference						
p = 0.05	4.03	4.26	2.97	6.32	2.11	
p = 0.01	5.35	5.66	3.95	8.40	2.80	
p = 0.001	6.96	7.37	5.14	10.93	3.64	
C. of V. %	36	35	22	17		

KISII VARIETY TRIAL: SOUTH NYANZA

Site: Deep red loam; each tree box ridged.
Date Planted: 1950.
Spacing: 9 ft. × 9 ft.
Shade: None.
Pruning System: Multiple Stem.
Trial Commenced: 1950.

Layout

A 7 × 7 Latin Square with 9-tree plots.

Results

TABLE XXXIX
(Yields in cwt. of clean coffee per acre)

Variety	1953	1954	1955	1956	Mean annual yield
SL.28	1.08	7.83	4.10	14.93	6.99
SL.14	1.57	8.22	2.71	14.10	6.65
Kenya Selected	0.43	6.50	2.77	12.83	5.63
Thorolds	0.68	6.66	2.99	12.08	5.60
Kents	0.48	6.35	3.51	10.17	5.13
KIT.145	0.86	5.43	2.44	10.86	4.90
Blue Mountain	0.70	4.72	3.49	10.45	4.84
Least Significant Difference					
p = 0.05	0.60	1.04	1.62	2.34	
p = 0.01	0.81	1.40		3.15	

The outstanding feature of the four recorded crops has been the performance of the selections SL.28 and SL.14, which have produced over 1 cwt. of clean coffee a year more than any of the other varieties under test.

WUNDANYI VARIETY TRIAL: TEITA

Site: Bench terraced.
 Date Planted: 1950.
 Spacing: 9 ft. × 9 ft.
 Shade: None on trial area but a shelter belt on two sides.
 Pruning System: Multiple Stem.
 Trial Commenced: 1950.

Layout

A 6 × 6 Latin Square with 6 trees per plot.

Results

TABLE XL
(Yields in cwt. of clean coffee per acre)

Variety	1954	1955	1956	Mean annual yield
Kents	12.64	18.66	3.40	11.57
K.7	10.74	18.08	3.98	10.93
KP.532	9.58	19.42	3.32	10.77
SL.28	7.92	19.41	4.98	10.77
SL.34	9.30	17.97	4.78	10.68
SL.14	7.53	14.52	5.53	9.19
Least Significant Difference				
p = 0.05	3.90	4.23	1.65	
C. of V. %	34.00	19.5	31.5	

Table XL shows that there has been little difference in the mean annual yield for the first three crops, though in the first crop picked in 1954 Kents significantly outyielded both SL.14 and SL.28. In the very large crop of 1955 KP.532 and SL.28 yielded more than SL.14, whereas in 1956 when the general level of cropping was low SL.14 yielded significantly more than KP.532 or Kents and SL.28 outyielded KP.532.

MERU SEED FARM VARIETY TRIAL: MERU DISTRICT

Site: 20% slope of dark-brown—dark-red soil of volcanic origin; box terraced; altitude 5,500 ft.; rainfall 53 in. per year (10 years' records).
Date Planted: 1951.
Spacing: 9 ft. × 9 ft.
Shade: None.
Pruning System: Multiple Stem.
Trial Commenced: 1951.

Layout

A 5 × 5 Latin Square of 9-tree plots.

Results

TABLE XLI

(Summary of results 1954-1956 in cwt. clean coffee per acre)

(Yields converted from cherry to clean coffee by dividing the cherry weight by 6)

Variety	1954/1955			1955/1956			1956/1957			Mean annual yield
	1st crop	2nd crop	Total	1st crop	2nd crop	Total	1st crop	2nd crop	Total	
SL.28	10.39	13.76	24.15	3.89	5.61	9.50	11.70	11.84	23.54	19.06
SL.34	9.14	10.14	19.28	5.56	3.85	9.41	13.74	12.55	26.29	18.33
Kenya Selected	11.27	9.89	21.16	2.91	2.79	5.70	10.63	13.47	21.16	16.99
N.100	7.35	6.69	14.04	5.84	3.41	9.25	10.81	8.63	19.44	14.24
Meru Kents	6.51	4.85	11.36	2.98	3.25	6.23	8.45	9.60	18.05	11.88
Least Significant Difference										
p = 0.05	2.79	4.30			2.93		4.54	5.47		
p = 0.01	3.93	6.06			4.13		6.39	7.70		
C. of V. %	23	35			56		30	35		

In Meru District two distinct harvests are picked in each year so that in Table XLI each year's total picking is divided into a first and a second crop. In the first three years the Scott Laboratories' Selections SL.28 and SL.34 have yielded particularly well, but Meru Kents has produced relatively low crops. This trial is likely to be important in the future as little is known of the long-term effect on the coffee tree of producing nearly a ton of clean coffee each year. Unfortunately, individual plot yields are not available for the first crop of the 1955/1956 season, so no three-year aggregate analysis is possible.

CHOGORIA VARIETY TRIAL: MERU DISTRICT

Site: 15% slope of fine red soil of volcanic origin; box terraced; altitude 5,100 ft.; rainfall 62 in. per year (10 years' records).
Date Planted: 1951.
Spacing: 9 ft. × 9 ft.
Shade: None.
Pruning System: Multiple Stem.
Trial Commenced: 1951.

Layout

A 5 × 5 Latin Square with 9-tree plots.

Results

TABLE XLII
(Summary of results 1954-1956)
(Yields in cwt. clean coffee per acre)

Variety	1954-1955			1955-1956			1956-1957			1955-1956	1954-1956
	1st crop	2nd crop	Total	1st crop	2nd crop	Total	1st crop	2nd crop	Total	2-year mean	3-year mean
SL.18 . . .	8.34	11.60	19.94	2.98	2.93	5.91	26.68	2.03	28.71	17.31	18.19
SL.9 . . .	10.57	7.96	18.53	2.71	2.53	5.24	23.73	4.66	28.39	16.82	17.39
SL.28 . . .	9.03	9.83	18.86	2.99	2.44	5.43	19.37	5.70	25.07	15.25	16.45
Meru Kents . . .	4.01	4.85	8.86	2.64	2.52	5.16	18.85	7.34	26.19	15.68	13.40
Mocha . . .	9.59	4.42	14.01	0.96	1.95	2.91	15.58	2.90	18.38	10.65	11.77
Least Significant Difference											
p = 0.05 . . .				1.50	1.30		4.45	2.20		4.35	
p = 0.01 . . .							6.30	3.05		6.03	
C. of V. % . . .				48	38		16	35		10	

As in the case of the Trial at the Meru Seed Farm, two crops are picked each year so that in Table XLII, which gives the results for the first three years of production, yields are given for six pickings. Unfortunately, pickings were bulked by varieties in the 1954/1955 season so no statistical analysis of these figures is possible. Both the two-year and the three-year means place the five varieties in the same order with SL.18 at the top of the table and Mocha at the bottom; however, the statistical analysis of the yields for the total of the 1955/1956 and 1956/1957 seasons showed no significant difference between varieties although significant differences were recorded between varieties in both crops of the 1956/1957 season.

IGEMBE VARIETY TRIAL: MERU DISTRICT

Site:	A moderate slope of red soil of volcanic origin; box terraced; altitude 4,200 ft.; rainfall about 90 in. per year.
Date Planted:	1951.
Spacing:	9 ft. × 9 ft.
Shade:	None.
Pruning System:	Multiple Stem.
Trial Commenced:	1951.

Layout

A 5 × 5 Latin Square with single-tree plots.

Results

While this is a miniature observation trial not designed to give precise information on the yields of the several varieties, it is included here to indicate the level of precision attainable with this design and also to give a guide to the performance of these varieties under a rainfall of about 90 in. per year and under conditions which induce two distinct crops each year.

TABLE XLIII

Summary of results 1955-1956 in cwt. clean coffee per acre

(Yields converted from cherry to clean coffee by dividing the cherry weight by 6)

Variety	1955/1956			1956/1957			Mean annual yield
	1st crop	2nd crop	Total	1st crop	2nd crop	Total	
SL.28	0.88	7.77	8.65	0.79	22.88	23.67	16.16
Dalle	1.84	6.93	8.77	2.42	10.54	12.96	10.87
Meru Kents	0.61	6.11	6.72	0.99	13.43	14.42	10.57
N.39	1.34	5.95	7.29	1.80	11.22	13.02	10.16
Blue Mountain	0.13	5.28	5.41	1.79	12.20	13.99	9.70
<i>Least Significant Difference</i>							
p = 0.05	1.75	2.84		2.07	6.40		
p = 0.01	2.46	3.99		2.91	9.01		
C. of V. %	133	32		96	33		

Only in the second crop of the 1956/1957 season has a significant difference been recorded between varieties. In this harvest SL.28 produced about twice as much coffee as any of the other varieties and it is largely as a result of this crop that SL.28 heads the other varieties in Table XLIII.

TIGANIA VARIETY TRIAL: MERU DISTRICT

Site: Level fertile red soil of volcanic origin; box terraced; altitude 4,700 ft.; rainfall about 46 in. per year.

Date Planted: 1951.

Spacing: 9 ft. × 9 ft.

Shade: None.

Pruning System: Multiple Stem.

Trial Commenced: 1951.

Layout

A 5 × 5 Latin Square with single-tree plots.

Results

TABLE XLIV

Summary of results 1955-1956 in cwt. clean coffee per acre

(Yields converted from cherry to clean coffee by dividing the cherry weight by 6)

Variety	1955/1956 1st crop	1956/1957 1st + 2nd crop	Total from 3 crops
SL.9	10.18	8.63	18.81
SL.28	10.63	5.59	16.22
N.100	10.94	5.75	16.69
SL.34	6.93	4.55	11.48
Meru Kents	2.79	7.03	9.82
<i>Least Significant Difference</i>			
p = 0.05	6.81	6.62	
C. of V. %	60	76	

Unfortunately no yield recordings were made before the first crop of the 1955/1956 season and then the yields of the second crop of this season are also unavailable. Both crops of the 1956/1957 season were recorded and such figures as are available are brought together in Table XLIV. The coefficients of variation are so high that even the very considerable differences between the varieties which occurred in the 1956/1957 season fail to reach statistical significance.

EMBU INVESTIGATION CENTRE VARIETY TRIAL: EMBU DISTRICT

Site: A gentle slope of Kikuyu Red Loam; box terraced; altitude 4,900 ft.;
rainfall about 45 in. per year.
Date Planted: 1950.
Spacing: 9 ft. × 9 ft.
Shade: None.
Pruning System: Multiple Stem.
Trial Commenced: 1950.

Layout

A 5 × 5 Latin with 9-tree plots.

Results

TABLE XLV

Summary of results 1953-1956 in cwt. clean coffee per acre

(Yields converted from cherry to clean coffee by dividing the cherry weight by 6)

<i>Variety</i>	<i>1953</i>	<i>1954</i>	<i>1955</i>	<i>1956</i>	<i>Mean annual yield</i>
SL.34	12.36	18.94	13.41	13.51	14.56
SL.14	9.20	22.36	15.41	11.23	14.55
SL.28	10.35	18.89	13.64	13.36	14.06
N.197	9.47	16.65	14.41	10.20	12.68
Kents	10.52	14.96	12.38	10.80	12.17
<i>Least Significant Difference</i>					
p = 0.05	3.19	4.51		3.03	
p = 0.01	4.43	6.32		2.92	
C. of V. %	22.2	17.9	29.2	12.5	

The yields recorded from the first four crops are presented in Table XLV which shows that only in 1954 and 1956 were significant differences between varieties recorded. In 1954 SL.14 yielded more than Kents or N.197 and in 1956 SL.28 and SL.34 significantly outyielded all other varieties under test. From the mean annual yields it may be seen that in the first four crops there has been little difference between the three Scott Laboratory Selections, and that N.197 and Kents have produced less coffee than the other selections. These differences have yet to be analysed more precisely.

AGRICULTURAL CHEMISTRY

SOIL NITROGEN AND RELATED STUDIES

Since 1954 the major investigation project of the Chemistry Section has been the study of various aspects of soil nitrogen availability and uptake in relation to climate, i.e. rainfall seasons, nitrogenous fertilizers, mulches, yields and vegetative growth of the coffee tree. For purposes of clarity various facets of the work are presented here under individual sub-headings. This is done so that some order can be brought to bear on the several points being investigated, but, of course, the results obtained are only part of the dynamic system, soil nitrogen, plant nitrogen, plant growth and crop yield.

In any study of a complicated dynamic system within a natural environment it is very difficult, if not impossible, to control and/or assess all the variables influencing the measured end point in any one experiment. To try to do so leads to insuperable problems. In this work a number of independent investigations have been carried out under both field and laboratory conditions, which can be interconnected by some common factor(s).

The investigation stemmed from the observed yield increases obtained with the use of nitrogenous fertilizers, i.e. ammonium sulphate and subsequently urea, in fertilizer trials carried out on this Station, and because it was considered desirable that an understanding should be sought of the relationship(s) between nitrogen fertilizers and organic grass mulches.

Nitrogen mineralisation in the field.

One of the first studies was that of natural inorganic nitrogen (ammonia, $\text{NH}_3\text{-N}$, and nitrate, $\text{NO}_3\text{-N}$ nitrogen) trends and fluctuations in relation to climatic conditions. During 1952 and 1953 an experiment was laid down in unmulched single-stem and multiple-stem pruned coffee. A description of the experimental layout and a summary of results has been recorded previously (1, 2). It was found that:

(a) $\text{NO}_3\text{-N}$ and to a lesser extent $\text{NH}_3\text{-N}$ values in the top 2 ft. of a Kikuyu red loam coffee soil were related to effective rainfall, i.e. rainfall which actually resulted in increased soil moisture values for a number of days with or without substantial water movement downwards through the soil profile.

(b) $\text{NO}_3\text{-N}$ values in the soil built up during the dry periods between the end of the Long Rains and the onset of the Short Rains, and from the end of the Short Rains to the onset of the Long Rains. This was particularly noticeable in the top 6 in. of the soil profile. $\text{NH}_3\text{-N}$ was accumulated within the top 2 ft. of the profile when soil moisture values occurred at or below the permanent wilting percentage; this $\text{NH}_3\text{-N}$ quickly disappeared when the soil moisture level increased at the onset of the Short Rains and was presumably readily nitrified.

(c) With the onset of the Long Rains $\text{NO}_3\text{-N}$ values which were high in the upper 2 ft. of the profile quickly decreased following movement downwards of soil moisture. $\text{NO}_3\text{-N}$ peaks were observed with time and depth, i.e. at increasing time intervals from the onset of heavy rains $\text{NO}_3\text{-N}$ peaks occurred successively at increasing depths. At the same time growth was taking place in the coffee and some $\text{NO}_3\text{-N}$ was undoubtedly removed by the crop and by the weed growth present.

Thus, in years of "normal" rainfall distribution, natural topsoil $\text{NO}_3\text{-N}$ is rapidly depleted, and this finding, when considered together with the recorded growth curve of the tree, led to the recommendation that nitrogen fertilizer should be applied during the first third of the rains (3) and not during the last third, as had been the practice previously.

The results obtained in this initial investigation were supported by a short-term investigation carried out during the Short Rains 1953 (4) in which it was demonstrated that natural soil $\text{NO}_3\text{-N}$, and $\text{NO}_3\text{-N}$ derived from Long Rains nitrogen fertilizer residues, was present in the soil at an earlier time in the Short Rains period than $\text{NO}_3\text{-N}$ derived from fertilizer application during the Short Rains. In relation to growth and recovery of the tree after heavy cropping, early nitrogen fertilizer application in the Short Rains period, as opposed to mid or late short rains applications, will lead to

maximum $\text{NO}_3\text{-N}$ production in the soil and therefore be of the greatest value for assisting growth at that time.

Following this work a number of short-term investigations of nitrogen mineralization in the field were started, together with two long-term experiments in the field.

The influence of the presence of weed growth in mature coffee during the Long Rains was investigated in terms of soil $\text{NO}_3\text{-N}$ and $\text{NH}_3\text{-N}$ (5) and total coffee leaf nitrogen (6). Weed growth had little effect on the relative distribution of $\text{NO}_3\text{-N}$ and $\text{NH}_3\text{-N}$ within the top foot of the soil profile, but it did lower the concentration of $\text{NO}_3\text{-N}$ found at the various sampling depths. In terms of coffee leaf nitrogen content, unrestricted weed growth resulted in a coffee leaf with approximately 15% less nitrogen in the dry matter.

In the Long Rains 1956 an experiment (No. 1) was laid down on a fallow soil area to compare the mineralization of ammoniacal and nitrate nitrogen fertilizers, under natural climatic conditions in the presence or absence of a mulch cover and without the complicating presence of a coffee crop. Some of the early 1956 results are described in Tables XLVI and XLVII. There are two replications of nine factorial treatments. The two replications are two fallow soil plots previously used for soil moisture recording, which had been kept free of any weeds or crop for a period of at least five years. It was assumed, therefore, that a reasonable state of nitrogen equilibrium existed among the many forms present in the soil at the time this experiment started. Soil samples have been taken by auger, bulking three sub-samples per plot per sampling depth. Actual times of sampling have been related to treatments and climatic conditions. The major restriction has been placed on sampling depth because of the limited number of soil samples which it is possible to examine in a day. Thus, results are restricted to the changes which occur in the top foot of the profile, a depth within which previous studies have shown the greatest activity to take place.

TABLE XLVI

A summary of main effects and overall nitrogen : mulch interactions for the long rains period 11.5.56 to 19.6.56
(Means of 36)

Treatments		(1)	Ammonium Sulphate	Sodium Nitrate	Means (of 108)
(1)	a	13.9	23.5	53.6	30.3
	b	4.63	25.67	4.99	11.73
	c	34.7	33.4	32.9	33.7
Napier Grass Mulch	a	17.8	31.5	55.2	34.8
	b	6.31	10.0	4.72	7.01
	c	40.4	40.9	40.2	40.5
Stone Mulch	a	19.8	23.1	38.8	27.2
	b	4.17	10.41	5.63	6.74
	c	40.7	40.8	39.1	40.2
Means (of 108)	a	17.2	26.0	49.2	L.S.D.s (Means of 108)
	b	5.04	15.36	5.11	
	c	38.6	38.3	37.4	
L.S.D.s	a	10.9*; 14.8*			6.5*; 8.3**
(Means of 36)	b				6.17*; 8.34**

- Notes: 1. $\text{NO}_3\text{-N}$ and $\text{NH}_3\text{-N}$ values in parts per million oven dry soil; moisture values in per cent.
2. a = $\text{NO}_3\text{-N}$ data; b = $\text{NH}_3\text{-N}$ data; c = moisture values.
3. Mulches applied 10.4.56; nitrogen fertilizers applied 11.5.56.
4. * = Statistically significant at 5% point; ** = 1% and *** = 0.1% points.

The application of the fertilizers has resulted in high soil $\text{NO}_3\text{-N}$ values in the top foot, and these values have persisted into the drier weather at the end of the Long Rains. This is the result partly of later fertilizer application and to only slight falls of rain following application (see Table XLVII). On May 11 coffee growth was past the peak and reference to Table XLVII will show that large quantities of $\text{NO}_3\text{-N}$ were not available in the soil to which ammonium sulphate had been applied until a further ten days had passed. By this time the rate of the coffee growth had decreased very markedly.

Sodium nitrate application, of course, resulted in a high concentration of $\text{NO}_3\text{-N}$ in the soil after a very short time-lag following application. Ammonium sulphate fertilizer also resulted in high $\text{NH}_3\text{-N}$ values (see Table XLVII) in the soil which persisted through until the end of this sampling period.

The overall interaction of nitrogen fertilizers and mulches obtained in these early results shows an apparently reduced degree of nitrification under the inert stone mulch compared with the unmulched and Napier grass mulch treatments. The $\text{NH}_3\text{-N}$ difference between ammonium sulphate treatment in the presence and absence of mulches is probably complicated by a time-lag due to application of the fertilizer through the mulches, as opposed to a free soil surface. Soil moisture and temperature values (the latter not recorded here) are respectively higher and lower in the mulched plots compared with the unmulched soil and similar for the two types of mulches.

TABLE XLVII
Showing the effect of sampling time on levels of $\text{NO}_3\text{-N}$ and $\text{NH}_3\text{-N}$ in the upper foot
of the soil profile
(ppm oven dry soil)

Treatments		Days after application of fertilizers					
Rainfall between sampling times (inches)		0	5	11	17	24	39
		—	0.31"	0.71"	0.17"	0.83"	0.78"
Control (1)	a	6.6	10.4	13.6	14.1	14.0	24.8
	b	3.52	7.45	4.92	3.25	3.65	4.99
Ammonium Sulphate (S/A)	a	7.5	13.4	29.6	27.9	30.7	31.3
	b	3.97	72.20	18.59	34.01	21.43	3.86
Sodium Nitrate (N/S)	a	7.4	66.5	47.5	66.5	83.0	50.9
	b	4.21	10.42	3.83	2.91	5.30	3.31
Napier Grass Mulch (NGM)	a	8.5	10.2	16.3	18.7	18.6	34.5
	b	3.41	12.57	3.73	10.04	4.02	4.03
Stone Mulch (SM)	a	8.7	12.2	10.3	11.2	51.1	24.9
	b	2.25	6.70	4.93	3.76	4.12	3.30
S/A + NGM	a	5.9	13.0	40.0	40.6	56.0	33.6
	b	4.13	12.17	20.11	6.89	10.14	6.59
N/S + NGM	a	7.4	66.5	64.0	79.2	58.0	56.3
	b	5.25	7.20	4.29	3.49	3.25	4.86
S/A + S/M	a	6.6	20.6	24.8	29.7	32.4	24.8
	b	4.28	26.30	7.91	6.49	13.04	4.45
N/S + SM	a	4.9	47.8	61.1	51.4	44.2	23.4
	b	3.34	14.95	3.69	3.82	3.27	4.70
L.S.D.s (Means of 6)	a	30.0*; 45.5**					
	b	13.38*; 20.28**					

Notes: a = $\text{NO}_3\text{-N}$; b = $\text{NH}_3\text{-N}$.

Of considerable interest is the similarity between the $\text{NO}_3\text{-N}$ figures for the S/A and S/A+SM treatments compared with the much greater values obtained with the S/A and NGM treatment. The time-lag between fertilizer application and soil $\text{NO}_3\text{-N}$ level has been referred to previously. The application of sodium nitrate fertilizer has had no apparent influence on the $\text{NH}_3\text{-N}$ values found in the soil.

Rainfall following application of fertilizers was very scanty but a comparison of the $\text{NO}_3\text{-N}$ values for the N/S, N/S+NGM and N/S+SM treatments does not suggest a very great lag in

movement of the fertilizer through the mulch cover. (N.B. The mulch cover was thoroughly wet prior to making these applications.)

Between the Long and the Short Rains 1956, $\text{NO}_3\text{-N}$ values increased steadily to a lesser or greater degree under all treatments and were high until about the middle of November. At this time the topsoil had been well moistened by rainfall and the $\text{NO}_3\text{-N}$ values fell following leaching down below the one-foot level.

Influence of nitrogen fertilizers and mulch on growth, leaf nitrogen content and yield (No. II).

A second field experiment, to run concurrently with Experiment No. 1 discussed in the previous section, was laid down during the Long Rains 1956, in which the influence of various treatments was to be recorded in terms of total leaf nitrogen content, vegetative growth of the coffee tree, and yield per acre. The layout of the experiment is a randomized block with four replications, each replication consisting of ten single-tree plots. The treatments comprise ammonium sulphate and urea fertilizer applied at a rate of 4 cwt. ammonium sulphate per acre or the nitrogen equivalent as urea, in the presence and absence of Napier grass mulch. In addition, the time of nitrogen fertilizer application during the Long Rains is varied between (a) all the fertilizer in one application as in normal estate practice, during the first third of the rains, and (b) applied in four equal applications spaced at ten-day intervals, commencing with the first application at the same time as (a). This comparison was included primarily to observe the effect on the growth curve of the coffee, which is mature multiple stem. The layout is such that yield differences due to treatments would have to be very large to reach statistical significance, but the main emphasis of this experiment is on leaf nitrogen content and growth values with yield measurement a subsidiary. The treatments were expected to produce large effects on the leaf nitrogen content and vegetative growth of the tree, and it was not

TABLE XLVIII

Mean Yield for 1956/57 and Growth Measurements for the period 14.4.56 to 30.12.56

<i>Treatments</i>		(1)	<i>Mulch</i>	<i>Means (of 8)</i>
Control (1)	a	6.0	2.6	4.3
	b	100.0	135.8	100.0
	c	100.0	118.5	100.0
4 cwt. ammonium sulphate	a	9.7	6.3	8.0
	b	99.9	113.3	90.4
	c	109.7	109.7	100.6
4 × 1 cwt. ammonium sulphate	a	7.3	6.8	7.0
	b	110.9	115.8	96.1
	c	104.0	106.5	96.4
200 lb. urea	a	5.9	5.3	5.6
	b	104.9	98.6	86.3
	c	104.8	104.0	95.6
4 × 50 lb. urea	a	3.1	10.2	6.6
	b	100.4	103.2	86.3
	c	102.4	101.6	93.4
Means (of 20)	a	6.4	6.2	
	b	100.0	109.8	
	c	100.0	103.7	

- L.S.D.s: (a) Not significant.
 (b) Means of 4 = 14.2%*; 19.2%**; 25.6%***
 Means of 8 = 8.5%*; 11.5%** —
 Means of 20 = 4.4%*; 5.9%**; 7.8%***
 (c) Not significant.

Notes: a = yields in cwt. clean coffee per acre.
 b = growth elongation as per cent of the control.
 c = No. of nodes, i.e. leaf pairs, produced as a per cent of the control.

possible, for practical reasons, to have 20 tree plots. In Table XLVIII are given the yield records for the 1956/1957 crop season, and growth measurements to the end of the short rains 1956 growth surge. All growth recording was carried out by the Plant Pathology section staff, using techniques devised by Mr. R. W. Rayner. The mulch treatments were applied on March 9 and the nitrogen fertilizer treatments on April 11 respectively.

For the first year's results neither crop yield nor node count data (a and c in Table XLVIII) show statistical differences relating to treatments, but elongation measurements were very significantly influenced. The most outstanding effects were (a) a plus 35% increase in growth elongation of primaries in the mulch treatment compared with the control, and (b) the depressing effect on this physiologic characteristic where mulch and either of the nitrogen fertilizers were applied together. By way of explanation it should be pointed out that as the plot size was only one tree, Napier grass mulching was complete over the whole surface area (a square 10 ft. $\times$ 10 ft.) right up to the base of the stem and that nitrogen fertilizer was applied through the mulch. In estate practice complete mulching is not recommended nor is it carried out very often, and nitrogen fertilizers are applied to the bare soil surface after partial mulching has been completed. The marginal means emphasize the overall effect of the mulch treatment and the increase in growth resulting from it; they also show that the negative effect on growth of nitrogen fertilizer applied together with mulch has been greater with urea than with ammonium sulphate. In view of the recent increase in the use of urea fertilizer within the industry, greater attention will be paid to this aspect of these results as measured by crop yields. However, it is difficult to understand the reason for a depressing interaction on growth of mulch plus ammonium sulphate in relation to the results of Expt. No. 1, given in Tables XLVI and XLVII. A comparison of control, ammonium sulphate, mulch, and ammonium sulphate plus mulch treatments shows no apparent discrepancy between expected $\text{NO}_3\text{-N}$ trends. The $\text{NH}_3\text{-N}$ values are, however, much lower under mulch following ammonium sulphate application than they are in the unmulched soil which has received ammonium sulphate. Perhaps an indirect effect on the potential rate and/or degree of $\text{NO}_3\text{-N}$ formation becomes a limiting factor or perhaps the fertilizer is washed through the soil and out of the root range more quickly.

The time of application of the ammonium sulphate has apparently affected growth in favour of split application during the long rains. Four applications is perhaps rather an exaggerated degree of splitting in practice and will be restricted to two applications during 1957 on the basis of soil studies of available $\text{NO}_3\text{-N}$. The shape of the growth curve during the long rains 1956 has been altered by the total versus the split ammonium sulphate application treatments and this difference is illustrated alongside the control and mulch treatments in Figure I.

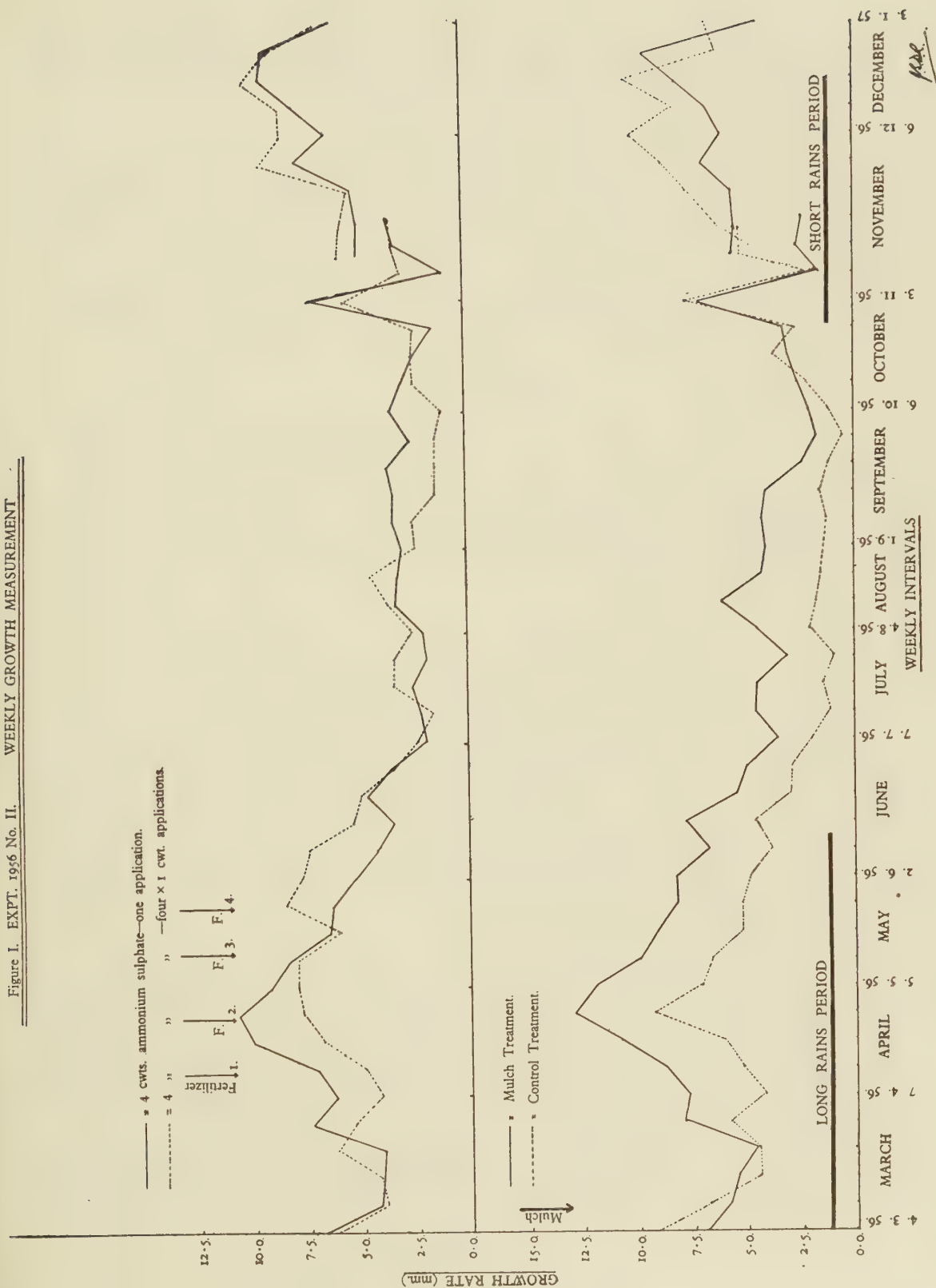
The shape of the growth curve for the mulch treatment is similar to that of the control treatment, whilst it illustrates the increased growth produced by the mulch application; the growth peak following a single application of 4 cwt. of ammonium sulphate per acre is less sharply defined and inclined to be broader than that of the control treatment, and this trend is even further accentuated most markedly by splitting the application into four equal parts. (Actual cumulative percentage growth values for these treatments are contained in Table XLVIII(b)). This split nitrogen fertilizer treatment has influenced the decline in the growth curve, which is a feature of growth records on this Station and which generally takes place somewhere in the middle or latter third of the Long Rains period. Climatic conditions which are moist, warm and sunny would seem to be ideal for continued growth at this time and these results would support the hypothesis that soil nitrogen becomes limiting to rapid growth after a period of continual precipitation.

The presence of mulch with 4 cwt. of ammonium sulphate, either as a single or as four equal applications, has not altered the shape of the growth curves from those shown in Figure I with the fertilizer alone. This only tends to confirm the influence of the fertilizer treatments on the shape of the growth curves.

The analysis of leaf samples taken in this trial has not proceeded far enough for conclusions to be drawn and no data will be presented here.

The use of urea fertilizer as a nitrogen source in the industry followed on the findings of an earlier study (7) into the relationship of ammonium sulphate fertilizer and soil pH. To avoid the probability of excessively acid coffee soil conditions resulting from the continual use of ammonium sulphate, urea was introduced in its place.

Figure I. EXPT. 1956 No. II. WEEKLY GROWTH MEASUREMENT



The overall conclusion to be drawn at the end of the first year of this experiment would appear to be that mulch with nitrogen fertilizer applied together in this way is perhaps not such an economic proposition in mature coffee as either of these treatments applied alone. Further years of records will, we hope, provide more definite information on this problem.

Effect of soil temperature on nitrogen mineralization in the field.

During the dry period of February-March, a short-term investigation into the influence of soil temperature on natural soil nitrogen mineralization under field conditions was carried out. Soil temperature records were determined by the electrical resistance technique (thermistors) which could be placed at a given soil depth very precisely. The experimental plot had been mulched fallow for a period of five years prior to the experiment and a fair degree of uniformity of total nitrogen in the topsoil was assumed.

A summary of results from some of the treatments is given in Table XLIX. The experiment was laid out as a randomized block, there being five replications of the four treatments.

TABLE XLIX

<i>Treatment</i>	<i>NO₃-N (ppm)</i>	<i>NH₃-N (ppm)</i>	<i>Soil Moisture (%)</i>	<i>Soil Temperature (°C.)</i>
A. 0-4 cm. topsoil removed; no mulch	32.8	4.66	22.5	37.2
B. 0-4 cm. topsoil present as a soil mulch	16.7	3.02	27.9	28.6
C. 0-4 cm. topsoil removed; stone mulch	14.2	3.41	34.6	27.9
L.S.D.s (means of 20)	9.5* 18.8**	0.63*	2.7* 5.3***	— —

Notes: Soil sample depth (original) 4-8 cm.

The order of magnitude of NO₃-N, NH₃-N and soil temperature may all be stated as follows: A₃ > B = C, whereas the soil moisture data give A < B < C. The immediate conclusion is that higher mean soil temperature and lower mean soil moisture has resulted in greater NO₃-N and NH₃-N values in the topsoil but this does not take into account the possibility of an upward migration of NO₃-N from the soil below the sampling depth in the absence of an insulating soil cover (mulch). However, as the NH₃-N mean value was also higher in the same treatment and since NH₃-N is not considered to be mobile in a bare unsaturated soil, some evidence does emerge for supposing that a greater degree of mineralization has taken place with higher temperature, and therefore that a thick mulch cover on the soil surface during dry periods between the rains will reduce NO₃-N and NH₃-N build-up in the topsoil (see 1, 2).

Influence of coffee roots on the nitrogen mineralization in the topsoil.

Towards the latter part of the Long Rains 1956 the influence of coffee roots on nitrogen mineralization and uptake by the tree of NO₃-N was examined under field conditions by isolating columns of soil. Columns 9½ in. square were isolated to a depth of 1 ft. by sinking 4-gallon petrol tins with the bottoms removed. The columns were isolated well within the root range of mature coffee trees, at a distance of 3 ft. from the trunk of the tree along the diagonal between two trees. (Spacing 10 ft. × 10 ft. square.) At the same time an equal number of soil points of 9½ in. square were selected at random and marked for future control plots.

The soil columns were isolated on May 8 and each column was sampled on the same day. A second sampling was carried out on May 21. Over this short period it was assumed that cut roots would not have decomposed to the extent of releasing substantial quantities of nitrogenous materials into the soil and so influence the analytical results.

Mean values for NO₃-N and NH₃-N second sampling are given in Table L.

TABLE L

Depth		Treatments (means of 6)		
		Soil Columns		
		Not Isolated	Isolated	Means (of 12)
0-3"	a	1.9	4.7	3.3
	b	5.0	4.6	4.8
3-6"	a	0.8	1.8	1.3
	b	4.1	3.8	3.9
6-12"	a	0.4	1.5	0.9
	b	3.6	3.6	3.6
Means (of 18)	a	1.0	2.7	—
	b	4.2	4.0	—
L.S.D.s (Means of 18)	a	1.4*		1.7*
	b	Not significant		0.7*

Notes: a = NO₃-N—parts per million oven dry soil.
b = NH₃-N—parts per million oven dry soil.

Levels of natural NO₃-N were low, a feature of the Kikuyu red loam coffee soil in East of the Rift Valley areas during the latter part of a Long Rains period; nevertheless, there was significantly more NO₃-N in the isolated than in the non-isolated columns of soil, to the extent of an apparent uptake by the coffee tree of 63 per cent. This calculation is based on the assumption of equality of formation of NO₃-N over the period between sampling dates. NH₃-N values did not differ significantly.

Foliar application of urea fertilizer.

During the Short Rains 1956 some preliminary tests were made with spray applications of urea fertilizer nitrogen on mature multiple-stem coffee.

A series of spray concentrations ranging from 100 lb. urea/100 galls. acre, through 50 lb. urea/100 galls. acre, 25 lb. urea/100 galls., 10 lb. urea/100 galls., 5 lb. urea/100 galls., to 1 lb. urea/100 galls. were applied at a rate of 1½ pints per tree with the following results:—

100 lb. urea/100 galls. — severe scorch of young foliage particularly where solution collected on leaf edges.

50 lb. urea/100 galls. — as above but with less severity.

25 lb. urea/100 galls. — negligible damage—occasional slight scorch on very young growth.

10, 5, 1 lb. urea/100 galls. — no effects observed.

At 25 lb. or less no adverse effect was noted on green cherry or spike or flowers.

In a second test, 25, 20, 15 and 10 lb. urea/100 galls. water were compared. Again a very slight degree of scorch was noted at the 25 lb. urea rate, but none was observed at lower concentrations.

A spray combination of a proprietary copper oxide powder* (50% copper) at the anti-leaf-fall level and 25 lb. urea/100 galls. water/acre was applied. There were no adverse effects observable on the foliage resulting from this combination and from that point of view there is nothing against spraying the mixture on to coffee. Whether the urea interferes with the efficiency of the "Perenox" is another matter. No chemical interaction seems likely, but a physical effect or antagonism could be present.

In an endeavour to reduce the volume of water required for urea spraying, a low volume/high concentration spray was applied with a knapsack power turbine sprayer. 150 lb. urea/100 galls. was applied at ¼ pint of spray per tree. The droplet-size distribution was not good and some very severe scorch was subsequently observed where droplets had coalesced on the leaf surface and run down on to the edge of the leaf. A very efficient ultra-low-volume type sprayer will be necessary for this type of application.

The results of these tests will be utilized to lay down a full-scale yield trial during 1957 in which ground versus spray application will be compared.

*"Perenox."

Nitrogen content of coffee foliage.

In some of the nitrogen $\pm$ mulch experiments being carried out on this Station coffee leaf samples have been collected for analysis of the total nitrogen content. This value is being determined by a method developed in the laboratory (8) and the results studied in relation to the fertilizer and mulch treatments in the field.

In the Short Rains 1955 and Long Rains 1956 a preliminary trial (five replications of a randomized block layout) to investigate the influence of nitrogen fertilizer on leaf nitrogen values was conducted. The mean results are summarized in Table LI.

TABLE LI
Nitrogen per cent in dry matter of first pair of fully hardened leaves

<i>Sampling Date</i>	<i>Treatment (Means of 5)</i>			<i>Means (of 5)</i>
<i>Short Rains 1955</i>	(1)	<i>4 cwt. S/A per acre</i>	<i>4 $\times$ 1 cwt. S/A per acre</i>	
29.10.55	2.076	2.091	2.005	2.057
9.11.55	2.071	2.071	2.072	2.071
18.11.55	1.984	2.057	1.888	1.977
28.11.55	2.105	2.175	2.007	2.096
Means (of 20)	2.009	2.099	1.993	—
L.S.D.s	<i>No significant difference</i>			0.072*
<i>Long Rains 1956</i>				
23.4.56 (mid)	2.128	2.133	2.102	2.121
19.5.56 (late)	2.118	2.146	2.207	2.160
18.6.56 (end)	2.040	2.083	2.078	2.067
Means (of 15)	2.095	2.120	2.132	—
L.S.D.s	<i>No significant difference</i>			0.042*

Notes: 1. Fertilizer treatments were applied on 18.10.55, and the three subsequent dressings of 1 cwt. ammonium sulphate on 29.10.55, 8.11.55 and 18.11.55.

Although the crop had been picked prior to the fertilizer applications and the trees (mature multiple stem) left in a condition to make maximum vegetative growth, very little was in fact made, probably because of poor rainfall conditions (4.85 in. from October 1 to November 28, mostly in very small showers which were largely ineffective).

The Long Rains 1956 data represent an attempt to estimate the residual fertilizer effect on leaf nitrogen content. In neither the Short nor the Long Rains have the fertilizer treatments given significant increases of total leaf nitrogen. This might conceivably be the effect of increased leaf production stimulated by the nitrogen fertilizer, which has resulted in more leafage of a similar nitrogen content to the untreated trees. This point is now under investigation in trials previously described in this report where both growth and total leaf nitrogen data are being collected simultaneously. However, during both periods of sampling, the time of sampling has had a significant effect upon the mean total leaf nitrogen content. The lowest mean value during the Short Rains was found in samples taken just after mid November following a dry period; ten days later, however, the value had increased significantly. During the residual sampling in the Long Rains 1956, the lowest mean value occurred in the sampling at the end of the rains. For two to three weeks prior to this sampling time soil $\text{NO}_3\text{-N}$ values had been low and the rate of growth was rapidly declining; the coffee had also flowered and set the main crop which was in the early stages of maturity. It is therefore difficult to even suggest what particular condition, or more likely conditions, produced the state of lowered total leaf nitrogen.

During 1955/1956 leaf samples were collected from the Plant Pathologist's shade trial experiment where growth measurements are being recorded in relation to factorial combinations of artificial shade, crop, irrigation and pruning system treatments. The leaf samples were processed and sent to the Colonial Products Laboratory, Imperial Institute, London, for full spectrographic analysis of some macro and micro nutrients. Sub-samples were retained for total Kjeldhal nitrogen determinations and a summary of the mean results, as per cent in dry matter, is given in Tables LII and LIII. The first (i.e. youngest) pair of fully hardened leaves were sampled in all cases. All leaves were from primaries and these in turn were selected at random from within given sections of a tree to ensure adequate sampling cover.

TABLE LII

*Single-stem mature coffee: effects of $\pm$ shade[†] and $\pm$ crop[×]
on total leaf nitrogen content (Means of 4)*

Treatments	Sampling Time				Means (of 16)
	1	2	3	4	
Crop Shade	1.810	2.398	2.457	2.014	2.169
No Shade	1.815	2.274	2.363	2.079	2.133
Means (of 8)	1.812	2.336	2.410	2.046	2.151
No Crop Shade	1.982	2.391	2.322	1.950	2.161
No Shade	2.004	2.256	2.313	2.067	2.160
Means (of 8)	1.993	2.323	2.317	2.008	2.161
L.S.D.s		0.119*	0.210***		
Overall Means (of 16)	1.903	2.330	2.363	2.027	
L.S.D.s		0.084*	0.149***		
Shade	1.909	2.266	2.338	2.073	2.165@
No Shade	1.895	2.395	2.390	1.982	2.147@
Means (of 16)	1.902	2.330	2.364	2.027	

- Notes: 1. [†]Metal strip artificial shade equal to 50% cover.
[×] No crop treatment stripped at the pinhead berry stage.
2. L.S.D. for means of 4 in body of table is 0.169*.
3. Figures in body of table Shade vs. No shade $\times$ time of sampling, are means of 8.
4. Sampling times were 22.8.55; 29.11.55; 10.4.56 and 8.6.56 respectively.
5. @ Means (of 32).

Time of sampling was related to various stages of the growth cycle of the coffee. The first sampling date was during a period of minimum growth when the weather was dull, cold and dry; the second sampling date was during the Short Rains growth surge; the third was during the following Long Rains growth surge and the fourth sampling date was at the end of the main growth period when the rate of growth had slowed down very considerably. Apart from the time of sampling which gave the largest individual significant differences, none of the single-factor treatments altered the leaf nitrogen results in this experiment significantly, and all other effects were confined to the interaction of the sampling time with $\pm$ crop or $\pm$ artificial shade. Samples taken during wet weather when active growth was taking place had higher total leaf nitrogen values than samples taken in dry, dull, cool weather (22.8.55) or moist weather when active growth was negligible or very slow (8.6.56).

A second set of analyses was made on samples taken to compare mature single- versus multiple-stem pruned trees $\pm$ crop, from plots within the same experiment.

TABLE LIII

Comparison of leaf nitrogen content between mature single- and multiple-stem coffee $\pm$ crop (Means of 2)

Treatments	Sampling Time				Means (of 8)
	1	2	3	4	
Crop	1.612	2.242	2.430	2.006	2.072
Single Stem					
No Crop	2.006	2.350	2.249	2.051	2.164
Means (of 4)	1.809	2.296	2.339	2.028	
Crop	2.227	2.286	2.460	2.210	2.296
Multiple Stem					
No Crop	2.004	2.331	2.251	2.209	2.199
Means (of 4)	2.115	2.308	2.355	2.209	
L.S.D.s	0.120*				
Means (of 8)	1.962	2.302	2.347	2.118	
L.S.D.s	0.085*;	0.120**			

Notes: L.S.D. for means of 2 in body of table is 0.171*.

Again the time of sampling has influenced the total leaf nitrogen content in the same manner as shown in Table LII for the previous set of data. An additional result of considerable interest is the significantly higher total leaf nitrogen content of multiple-stem coffee leaves at times when, overall, leaf nitrogen values are low, viz. the first and the last sampling times, when the coffee is not in a main growth surge period. Coupled with the similarity of values to the single-stem coffee during periods of rapid vegetative growth, viz. the second and third sampling times, this is most interesting. It might also have some relationship to an earlier aspect of soil nitrogen results (2) where it was shown that soil samples collected under multiple-stem pruned coffee had a very significantly higher mean $\text{NO}_3\text{-N}$ content than soil under mature single-stem coffee. Both these findings would be in favour of higher crop yields from multiple-stem pruned coffee.

During the Long Rains 1956 two of the main nitrogen fertilizer $\times$ mulch trials on the Station were sampled (youngest pair of fully hardened leaves on random primaries) to see whether the total leaf nitrogen contents could be related to field treatments. It is in the first of these trials that a negative nitrogen fertilizer $\times$ mulch interaction has been found, to elucidate which, the second trial sampled here, was initiated. Yield responses to treatments in this latter trial, although relatively new (commenced 1954), have been inconsistent, often confusing and sometimes even contradictory on some of the points under investigation.

In neither of these trials have the treatments significantly influenced the total leaf nitrogen at the time of sampling. All the sampling time the trees were growing actively and were bearing heavy crops of green cherry. However, in Trial I nitrogen fertilizer alone and with mulch appears to have given values slightly higher than those obtained for mulch alone or for the control treatments; in Trial II mulch and nitrogen fertilizer treatments also appear to have increased the total leaf nitrogen content. Applying the fertilizer to the bare soil as opposed to the mulched soil surface seems to have resulted in a higher leaf nitrogen figure.

It is concluded from all these results at this stage that the total nitrogen content of the first fully hardened leaf pair is not a very reliable indicator of fertilizer nitrogen uptake on the Kikuyu red loam coffee soils, but the information is far from complete. Data now being collected for leaf samples taken throughout the year in the Experiment No II referred to earlier in this report (page 55) will provide much more evidence on this point.

Laboratory incubation studies on the Kikuyu red loam coffee soil.

To obtain a closer understanding of the relationship between soil moisture and the mineralization of natural soil nitrogen, a series of laboratory experiments (incubation) have been carried out under controlled conditions of temperature and soil moisture. Some of these investigations have been

TABLE LIV

*Total nitrogen content of leaf samples taken in the Mulch and Soil
Regeneration Trial I and Nitrogen Trial II, Long Rains 1956*

<i>Treatment</i>	<i>Trial I Means (of 4)</i>	<i>Treatment</i>	<i>Trial II Means (of 6)</i>
(1) Control	2.279	(1) Control.	2.082
a. All inter-row mulch before rains	2.190	All inter-row mulch before rains (M2)	2.178
b. Alternate inter- row mulch before rains	2.292	6 cwt. ammonium sulphate acre (N6)	2.160
d. Ammonium Sul- phate (2 cwt./ acre)	2.457	M3 N6 P1	2.271
e. Nitrate of Soda (2 cwt./acre S/A.)	2.463	M3 N6 P2	2.198
a + d	2.318		
a + e	2.195		
b + d	2.392		
b + e	2.355		

- Notes:* 1. Nitrogen content expressed as percentage in Dry Matter.
 P_1 = Nitrogen fertilizer applied to the bare soil only.
 P_2 = Nitrogen fertilizer applied to mulch only.
 2. Time of sampling was Trial I = 23.5.56 and Trial II = 25.5.56.

carried out in parallel with field studies or in an endeavour to elucidate problems observed under field conditions.

During the course of an investigation in the field, where the trends of natural soil nitrogen mineralization under a mature coffee crop were being followed, accumulations of $\text{NH}_3\text{-N}$ were found during the dry months of September and early October (16). No obvious reason(s) for the accumulations, which occurred in the upper two feet of the soil profile, was forthcoming, so a series of laboratory experiments were started. It was shown that at low soil moisture values (less than the permanent wilting percentage) the formation of $\text{NO}_3\text{-N}$ (nitrification) in the topsoil quickly ceased, whereas the formation of $\text{NH}_3\text{-N}$ (ammonification) continued to take place down to considerably lower moisture levels (17).

Under laboratory conditions, the wetter the soil is between the permanent wilting percentage and field capacity values, the greater the $\text{NO}_3\text{-N}$ mineralization and the greater the $\text{NO}_3\text{-N}$ accumulation over a period of time. Under field conditions, the onset of the rains produces an initial and often short-term flush of $\text{NO}_3\text{-N}$ production, despite the build-up which has taken place during the dry weather (2). With a reasonable rainfall distribution during the Long Rains (and to a lesser extent during the Short Rains) the overall natural $\text{NO}_3\text{-N}$ level in the topsoil quickly falls and finally reaches a low minimum during May and early June. These low values which occur at certain periods under field conditions, when considered in relation to the results from laboratory incubation studies have, in the past, been attributed to uptake by the coffee tree and to downward movement through the soil profile (leaching) after this has been wet to the field holding capacity. Accumulation of $\text{NO}_3\text{-N}$ in the dry period following the Long and Short Rains has been attributed to rapid nitrification whilst the topsoil is drying out together with a much lower rate of uptake by the coffee tree at this time, and to a lack of leaching down through the soil profile.

This whole conception of $\text{NO}_3\text{-N}$ status under field conditions presupposes at least two main points: (a) that the rate of nitrification in the field is indeed higher under wet soil conditions during

the rains and during drying out of the soil at the end of the rains and (b) that the topsoil samples prepared for controlled laboratory incubation studies are not altered in any appreciable manner by air drying or oven drying, and storage, so that false values are recorded on which the interpretation of field behaviour will be based.

A comparison of maintaining the moisture level versus allowing the soil to dry out during incubation.

Three moisture levels were selected and in one replicated set of flasks they were maintained daily by water addition where necessary and in another set of replicates no additions of water were made after initial wetting. The results for nitrate and ammonia nitrogen are summarized in Tables LVa and LVb. The soil sub-samples were taken from a single bulk sample, air dried, ground to pass a 2 m.m. round hole sieve and stored for a few months prior to use.

TABLE LVa
Ammonia and nitrate nitrogen (ppm oven dry soil, Mean of 6)

Moisture Status		Moisture Level			Means (of 18)
		P.W.P.	$\frac{1}{2}$ F.C.	F.C.	
Drying Out	NO ₃ -N	12.1	32.5	43.8	29.5
	NH ₃ -N	9.34	2.49	2.17	4.67
Maintained	NO ₃ -N	22.0	41.6	58.7	40.8
	NH ₃ -N	4.87	1.60	1.39	2.62
Means (of 12)	NO ₃ -N	17.1	37.1	51.2	
	NH ₃ -N	7.10	2.04	1.78	

Notes: L.S.D.s NO₃-N Means of 12, 5.9*; 11.0***, Means of 18, 4.8*; 9.0***.
 NH₃-N Means of 12, 0.78*; 1.47***, Means of 18, 0.63*; 1.19***.
 P.W.P. = Permanent wilting percentage (22% H₂O).
 $\frac{1}{2}$ F.C. = Half field capacity.
 F.C. = Field capacity (41% H₂O) moisture levels.

TABLE LVb

Time Intervals		Drying Out	Maintained	Means (of 12)
8 days	NO ₃ -N	27.6	30.7	29.1
	NH ₃ -N	4.21	3.89	4.05
16 days	NO ₃ -N	31.0	39.1	35.1
	NH ₃ -N	4.43	2.44	3.43
32 days	NO ₃ -N	29.7	52.6	41.2
	NH ₃ -N	5.36	1.51	3.43
Means (of 18)	NO ₃ -N	29.5	40.8	
	NH ₃ -N	4.66	2.61	

Notes: L.S.D.s NO₃-N Means of 12 and 18 see Table X; Means of 6 = 8.3*.
 NH₃-N Means of 12 and 18 see Table X; Means of 16 = 1.10*; 2.06***.

From Table LVa it will be seen that if the soil moisture is maintained at a given level and does not dry out with time, NO₃-N is formed more quickly and accumulates to a higher level at the end of 32 days' incubation and that more total NO₃-N is accumulated at the higher moisture levels between the limits of the permanent wilting percentage and field capacity values. NH₃-N values are the reverse of the NO₃-N values, are greater at lower soil moisture values and are greater with drying out of the soil during incubation.

A similar experiment was carried out over an extended period of ten weeks with the same soil as before. Sub-samples were removed from the incubator at weekly intervals for analysis; they were initially wet to the field capacity moisture level only. The selection of a single soil moisture level

was justified because of the parallel nature of the results obtained in the previous experiment at the three different moisture levels. The trend of the $\text{NO}_3\text{-N}$ and $\text{NH}_3\text{-N}$ data was similar to that in the previous experiment. The final $\text{NO}_3\text{-N}$ figures after ten weeks were: Moisture level maintained, 160.9 ppm $\text{NO}_3\text{-N}$ and Moisture level not maintained 72.6 ppm $\text{NO}_3\text{-N}$.

Experiments to determine the influence of pre-drying soil samples (i.e. as in normal laboratory preparation) on their behaviour during incubation.

As a general rule soil samples for laboratory incubation studies are prepared by air-drying, breaking up and sieving, to produce a homogenous material which can be easily handled. It is assumed that upon re-wetting, the pattern of natural nitrogen mineralization or the mineralization of natural plus added nitrogen in some form will be resumed with little alteration. This assumption has presumably often been made by workers who have studied nitrogen mineralization under laboratory incubation conditions in relation to the behaviour of that soil in the field.

To examine whether this was in fact so, samples of topsoil (0-6" Kikuyu red loam coffee soil) were collected from a coffee field during a wet period in the Short Rains 1956. After rapid collection, sub-samples were weighed out and placed in incubation flasks inside the incubator. Overnight, the moisture content of the field soil samples was determined and the residual portion of the field samples was spread out on paper in a thin layer and dried in an air oven at 50-55°C. (A temperature of 50-55°C. was chosen for two reasons: (i) It is the highest range recorded during the hot dry season in the immediate topsoil of the Kikuyu red loam coffee soil and (ii) it was therefore the quickest way of drying out the soil within the field temperature range.)

The next day a weight of dry soil equal to that of the wet samples prepared on the previous day was measured out into a series of incubation flasks, re-wet to the original moisture level of the field sample and placed in the incubator alongside the earlier sub-samples. There was thus a days' difference in time between the two sets of soil sub-samples which were incubated under identical conditions. The results obtained in this experiment are illustrated in Figure II.

The curves in Figure II show that a pre-drying treatment of incubation soil samples at 50-55°C. does alter very significantly both the level and the actual trends of nitrogen mineralization. Under field moisture maintained conditions but otherwise in the incubator subjected to controlled temperature and moisture levels (35%) the soil is unable to produce more than about 28 ppm $\text{NO}_3\text{-N}$ whereas after pre-drying and re-wetting to the same moisture level (35%) 60 ppm $\text{NO}_3\text{-N}$ were produced over the same period of time. However, $\text{NH}_3\text{-N}$ is formed before $\text{NO}_3\text{-N}$ in the mineralization reaction, so that it looks as though pre-drying has either led to the release of $\text{NH}_3\text{-N}$ or, what seems more likely, has led to the release of readily ammonifiable organic matter and, therefore, to the high $\text{NH}_3\text{-N}$ value recorded at the 8-day sampling interval.

This effect is very interesting indeed and one wonders whether a similar effect occurs under field conditions following rainfall at the close of a drought period. This would account for the ready flush of $\text{NO}_3\text{-N}$ produced early in each rains. It would also seem that there is perhaps a limit to high $\text{NO}_3\text{-N}$ production in this soil after prolonged wetting (during a rains period) under field conditions (the soil sample for this study was collected towards the end of November and the $\text{NO}_3\text{-N}$ value of 6 ppm was quite low). If this is the case, then the low natural $\text{NO}_3\text{-N}$ values found towards the end of the main rain periods are the result not only of leaching from the topsoil and uptake by the coffee tree roots but also of a low nitrification level in the soil compared with earlier in the season.

These results might also be important in relation to soil incubation techniques where the aim is to correlate $\text{NH}_3\text{-N}$ and/or $\text{NO}_3\text{-N}$ produced under controlled conditions in the laboratory with nitrogen requirements in the field. This assumes that different soil types have a similar behaviour pattern.

These results were followed up by a further experiment in which the object was to study the influence of a number of alternate pre-drying and re-wetting treatments on the natural soil nitrogen mineralization. These results are illustrated in Figure III.

The bulk soil sample (0-6" Kikuyu red loam coffee soil) was taken from a coffee field on the Station.

FIGURE II

Experiment VI Effect of pre-drying a wet field soil
on its incubation performance.

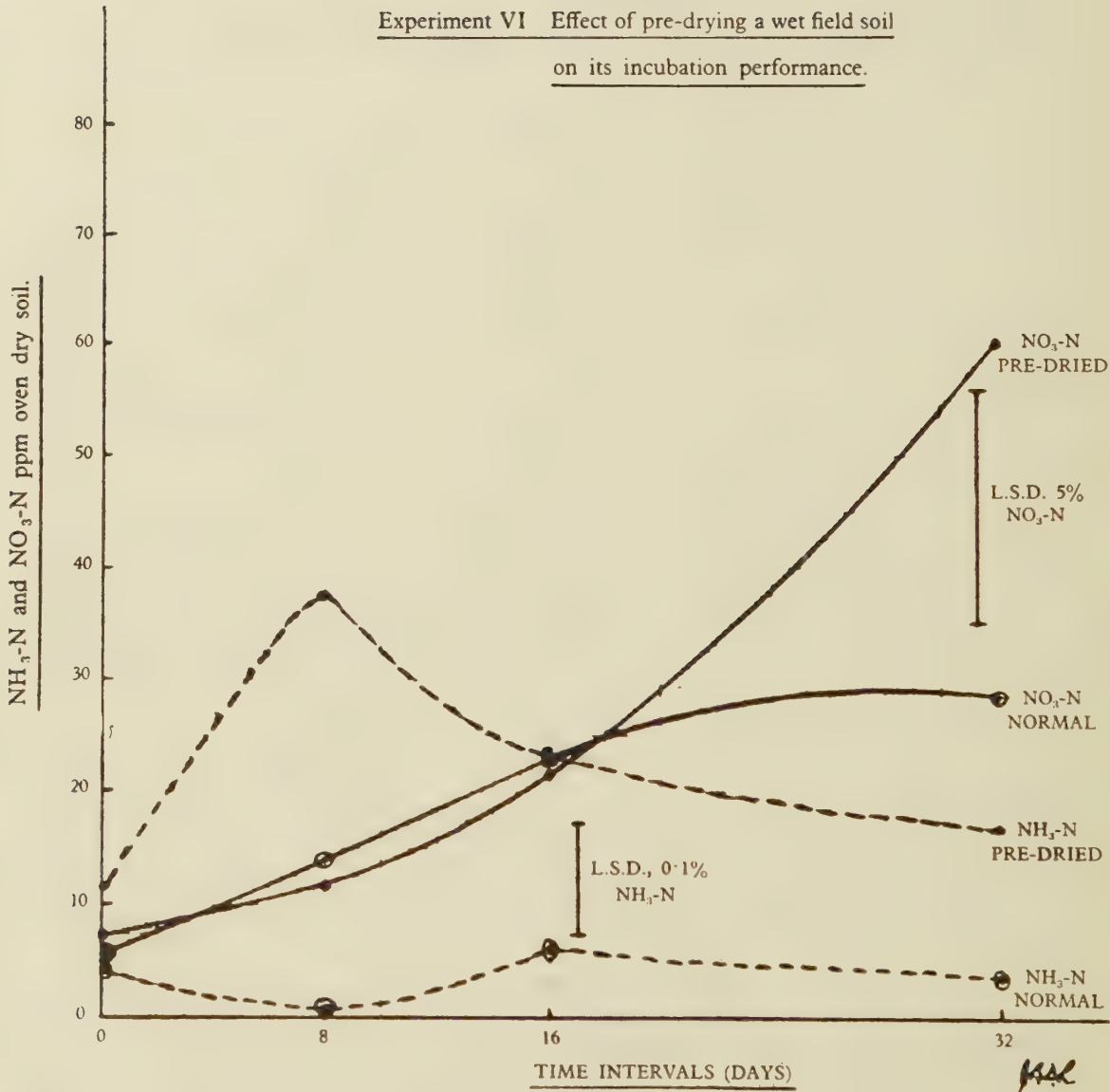
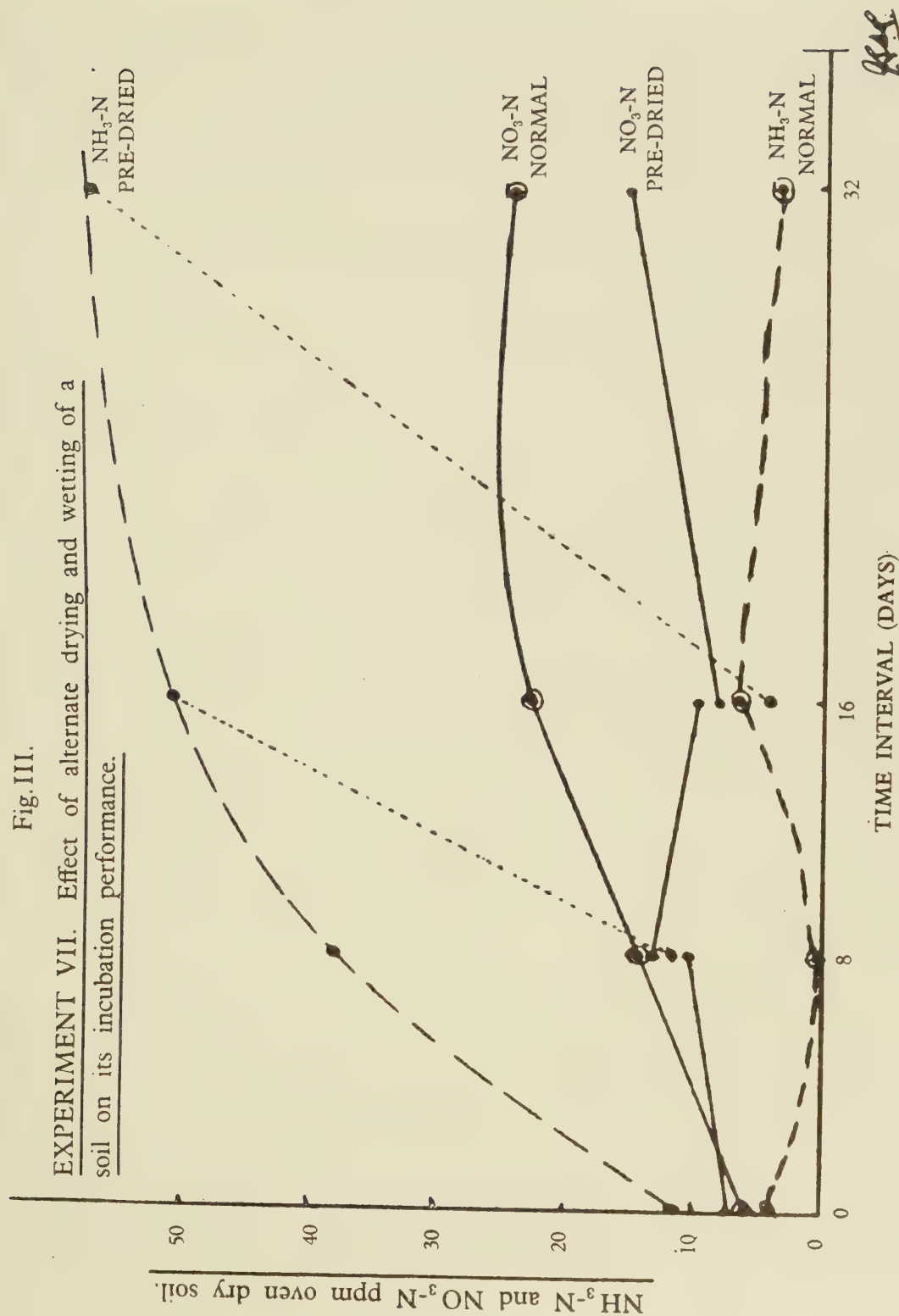


Fig. III.

EXPERIMENT VII. Effect of alternate drying and wetting of a soil on its incubation performance.



The moist soil as collected from the field (34% H_2O) was sub-sampled and incubated directly in duplicate. The curves marked NO_3-N and NH_3-N normal were obtained by graphing the mean value at each sampling interval. The residual bulk of the sample was oven-dried overnight at $55^\circ C$. and weighed sub-samples of the soil were made up the next day to the original field sample moisture content and incubated. At the 8-, 16- and 32-day intervals, duplicate flasks were removed for analysis, and the residual flaked samples were oven-dried overnight, re-wet to the initial field moisture value the next day and incubation was then continued. Thus samples analysed at the 8-, 16- and 32-day intervals had been oven-dried overnight once, twice and three times respectively at the 0-, 8- and 16-day time intervals. The NO_3-N and NH_3-N curves marked pre-dried represent the mean values obtained.

The outstanding effect of the repeated oven-drying has been to produce, directly or indirectly, a substantial release of NH_3-N . The fine dotted lines joining up a point at eight days to the 16-day value and a point at 16 days to the 32-day value represent the NH_3-N increase from immediately post pre-drying to the end of that interval.

For example: at the 8-day interval, the mean NH_3-N value for the soil pre-dried at 0 days before incubation was 38.5 ppm in the oven-dry soil. The following morning, after being overnight in the air oven at $65^\circ C$., this had fallen to 11.5 ppm. Similarly treated flasks were then replaced in the incubator and eight days later (16-day sampling interval) the mean NH_3-N value had risen to 51.2 ppm. Overnight pre-drying reduced this value to 4.3 ppm. The final batch of flask replicates were put back into the incubator and 16 days later (the 32-day sampling interval) the mean NH_3-N value had risen to 57.9 ppm.

Since each pre-drying treatment reduced the wet soil NH_3-N value very substantially, to a value of 11 ppm or less, each increase in NH_3-N following re-wetting and incubation signifies either a new release of NH_3-N from organic matter in the soil or a re-release of the NH_3-N which had been fixed or protected during the overnight oven-drying treatment. It is probable also that drying at $50-55^\circ C$. effects a partial soil sterilization with the release subsequently of NH_3-N , a phenomenon which is not unknown in steam sterilization practices.

Whatever the explanation may be of the phenomenon, temperatures in the field topsoil of $50-55^\circ C$. have been recorded and will have a similar effect, thus accounting for some NH_3-N accumulation in the topsoil. It will not account for all of it, however, as was shown in previous studies (17) which demonstrated accumulations at a temperature of $30^\circ C$. when the soil moisture level fell below the permanent wilting percentage. This latter mechanism would be operative in shaded topsoil (shaded coffee both self-shading and introduced tree shade) whereas the high temperature effect would not, or probably not, to anything like the same degree under field conditions.

Accumulation of NH_3-N in a soil which has been air-dried in preparation for incubation work will be effected in the second way noted above; quick drying in the oven between $45^\circ C$. to $55^\circ C$. will not prevent this accumulation, as the results described above will show. Thus to simulate, under laboratory conditions, nitrification trends and the build-up of soil NO_3-N as it might take place in the field, moist samples must be collected from the field and incubated immediately. This is now being undertaken in conjunction with a study of analytical techniques to evaluate readily available (in terms of nitrogen mineralization) soil nitrogen forms.

MAGNESIUM NUTRITION OF COFFEE

During the long rains 1956 a visual deficiency condition was observed on mature bearing coffee in some of the long-term mulch and soil regeneration trial plots on the Coffee Research Station. A joint investigation of the condition both in Kenya and Uganda coffee was undertaken in collaboration with Dr. E. M. Chenery of the Department of Agriculture, Uganda. A report of this study has been prepared for publication and details of the findings are not given here. The results may be summarized, in so far as the arabica coffee industry in Kenya is concerned, as follows: "*The magnesium deficiency syndrome for arabica coffee has been described in detail. The distribution of magnesium and potassium in branches of trees treated and not treated with Napier grass mulch are presented. The critical level of magnesium below which the syndrome is likely to occur and the leaves to drop prematurely is about 0.20% D.M. although cases have been quoted where the magnesium content is below 0.1% D.M. The critical ratio of potassium to magnesium in leaves is about 10 to 1.*"

"Mulching treatment with Napier grass has a strong tendency to induce magnesium deficiency by supplying an excess of antagonising potassium to the soil. Iron chlorosis is often associated with the deficiency. Frequently it was found that magnesium levels in cherry on deficient trees were similar to or even greater than those found in healthy trees, thus often tending to exaggerate the deficiency. The deficiency occurs mainly in the older leaves in whose axils cherries are developing."

The benefits of Napier grass mulching in terms of crop yield are such that the correction of this condition is now under investigation with magnesium fertilizer salts. A possible means of alleviating the onset of the condition lies in finding a grass with suitable mulching potential which has a lower potassium content than Napier grass. This latter material is a luxury consumer of potassium when grown on the fertile Kikuyu red loam soils which are rich in naturally available potassium.

A survey of leaf potassium and magnesium values was carried out in mature bearing coffee during August-September. A few representative estates were chosen at random within the Thika, Ruiru and Kiambu areas. Unfortunately, leaf samples were all collected from the current 1956 wood and none were taken from the 1955 wood. This resulted in a less sensitive range of analytical values as noted earlier in this section. Evidence, both visual and analytical, of magnesium deficiency, or imbalance, was obtained in all districts and was particularly noticeable in heavily bearing multiple-stem as distinct from single-stem coffee, and in heavily shaded coffee (*Grevillea* sp.), in the Kiambu area, as opposed to unshaded coffee.

The small magnesium survey trial commenced in 1954 (21) was continued during 1956. In this trial the results of magnesium fertilizer applications are being followed in terms of leaf analysis and crop yield. To date, the coffee in this trial has not been mulched, but in the light of work carried out this year (see previous paragraphs of this section) Napier grass mulching will be undertaken in 1957. The experimental layout is very simple; there are five replications of straightforward $\pm$ magnesium fertilizer treatments and the plot size is two mature multiple-stem trees.

The comparative yield data over three years (1954-1956) are control, 8.5 cwt. clean coffee per acre per annum and magnesium fertilizer treatment, 9.5 cwt. clean coffee per acre per annum, representing an apparent average yield increase of 1 cwt. of clean coffee per acre per annum. This figure is not statistically significant.

The leaf analysis data for 1955 and 1956 do not show significant leaf composition differences arising from the application of magnesium fertilizer. In the light of recent work this may be because the leaf samples taken were too young, i.e. the first pair of fully hardened leaves on a primary. It has been shown (see Table LVI) by detailed branch analysis that the old leaves on the bearing wood, particularly with crop present in the axils, show wider ranges of leaf magnesium in the presence of sub-optimal magnesium nutrition.

TABLE LVI
Branch Analysis of Bearing and Non-Bearing Mature Multiple-Stem Coffee
(Var. S.L.28)

<i>Mg deficient leaves present</i>		%K	% Mg.	K : Mg ratio
<i>Nodes.</i>	<i>Sample.</i>			
1956, non-bearing wood				
1—5	Leaf	2.12	0.41	5.1 : 1
6—10	Leaf	2.35	0.25	9.4 : 1
1955, bearing wood				
11—16 (a)	Leaf	3.10	0.07	44.3 : 1
(b)	Crop (Green Cherry)	2.18	0.23	—
17—21 (a)	Leaf	3.98	0.13	30.6 : 1
	Crop (Green Cherry)	2.45	0.26	—
<i>No visual deficiency, v. light crop</i>				
1956, non-bearing wood				
1—4	Leaf	2.35	0.41	5.7 : 1
5—7	Leaf	2.90	0.37	7.9 : 1
1955, bearing wood				
0—8	Leaf	2.87	0.31	9.2 : 1
9—17	Leaf	2.75	0.31	8.8 : 1
	Crop (Green Cherry)	2.36	0.29	—

Note: Analysis by G. T. Chamberlain, Spectrochemist, E.A.A.F.R.O.

However, although treatments did not significantly affect leaf composition there were significant differences in leaf magnesium, calcium and potassium at different sampling times during 1956, and the mean results are noted in Table LXVII.

TABLE LVII

Element (% in Dry Matter)	Crop →									Means (of 90)
	1 24/ 4/ 56.	2 25/ 5/ 56.	3 26/ 6/ 56.	4 25/ 7/ 56.	5 27/ 8/ 56.	6 26/ 9/ 56.	7 26/ 10/ 56.	8 26/ 11/ 56.	9 27/ 12/ 56.	
Potassium	2.99	2.41	3.04	2.42	2.42	2.63	2.41	2.70	3.13	2.68
L.S.D.s		0.20*		0.27**						
Calcium	0.97	0.96	0.94	0.84	1.08	1.04	1.00	1.16	0.82	0.98
L.S.D.s		0.09*		0.12**						
Magnesium	0.41	0.38	0.36	0.37	0.41	0.44	0.46	0.56	0.32	0.41
L.S.D.s		0.04*		0.05**						

The arrow over the sampling times represents the presence of crop, from pinhead to fully ripe. From the third (end of Long Rains) period to the seventh (beginning of Short Rains period) sampling time inclusive, rain was spasmodic and growth slight. Thus during crop maturation in the dry months potassium levels fell, whereas calcium and magnesium levels tended to rise. It is too early yet to attempt to interpret these trends with any degree of certainty.

In the early part of this section it was stated that the magnesium deficiency condition was related to Napier grass mulching. That this is so is shown also by soil analysis results from a comparison of mulched and unmulched treatments in the mulch and soil regeneration trial.

TABLE LVIII

Influence of Napier Grass Mulch on Exchangeable Calcium, Potassium and Magnesium in a Kikuyu Red Loam Coffee Soil

(M. eq. per cent of air dry soil)

Soil Depth	Unmulched			Mulched			Means (of 8)		
	K	Ca	Mg	K	Ca	Mg	K	Ca	Mg
0-6"	2.36	7.94	4.05	6.25	6.95	5.46	4.30	7.45	4.76
18-24"	0.88	5.85	4.07	2.22	3.96	3.18	1.53	4.91	3.63
Means (of 8)	1.62	6.89	4.06	4.23	5.46	4.32			
L.S.D.s	0.70*	1.08**	0.55*						
(Means of 8)	1.45***		1.13**						

Notes: (1) L.S.D.s for means of 4 (body of table) are Ca—not significant, Mg, 0.78*; 1.10**;
K, 1.00*; 1.42**.

(2) Soil extractions were carried out with Morgan's U.E.S. reagent.

(3) Samples were taken at the point of diagonal intersection between four trees planted 10 ft. x 10 ft. square.

It is apparent that the greatest influence of the mulching has been on soil potassium (K) levels which show a very marked and significant increase at both sampling depths. The magnesium levels in the mulched soil have apparently increased slightly at 0-6 in. and decreased at 18-24 in.; the calcium content of the soil was overall, lowered by the mulch treatment. (Mulching had been consistent for nine years prior to sampling.)

One other comparison of treatments was made in terms of potassium (K), calcium (Ca) and magnesium (Mg) from within the same trial area. This was to compare soil values for the control, mulch+cattle manure and mulch+ammonium sulphate treatments. Samples were again taken at 0-6 in. and 18-24 in. depths, but at a distance of $2\frac{1}{2}$ ft. from the tree trunk between two trees in adjacent rows (inter-row space, A) and between two trees within a single row (tree row space, B). Around any one tree two samples in position A and two samples in position B were taken, on opposite sides of the tree, and bulked for analysis. The significance of this difference in sampling lies not only in the actual positional difference (orientation, etc.) but in the fact that for the combination treatments of mulch + cattle manure and mulch + ammonium sulphate the soil at position A will have received both materials whereas at position B cattle manure or ammonium sulphate only will have been applied. The reason is that mulch is applied in the inter-row space; cattle manure and ammonium sulphate in a complete circle around the tree. The mulch and cattle manure treatments had been applied consistently for a period of nine years prior to sampling the soil; for the last three seasons the rate of cattle manure application was raised from one to two 4-gallon tins per tree. Ammonium sulphate had been applied for six years prior to sampling at 1 cwt. per acre for the first three years and at 2 cwt. per acre for the last three years.

TABLE LIX

The Influence of Napier Grass Mulch, Ammonium Sulphate and Cattle Manure on Exchangeable Calcium, Potassium and Magnesium in a Kikuyu Red Loam Coffee Soil
(M. eq. per cent of air dry soil; means of 4)

Sample Depth		Field Treatments					
		(1)		Mulch + Ammonium Sulphate		Mulch + Cattle Manure	
		A	B	A	B	A	B
0-6"	Ca	8.43	8.39	9.11	9.05	10.66	7.71
	K	2.30	2.01	4.46	2.98	9.40	3.51
	Mg	4.16	3.73	3.44	3.81	5.70	6.05
Means (of 8†)	Ca	8.41		9.08		9.19	
	K	2.16		3.72		6.45	
	Mg	3.94		3.62		5.88	
18-24"	Ca	5.20	5.43	6.79	6.44	5.84	4.64
	K	1.20	1.14	1.95	1.52	3.19	1.53
	Mg	3.66	3.54	3.54	3.45	3.61	3.39
Means (of 8†)	Ca	5.31		6.62		5.24	
	K	1.17		1.74		2.36	
	Mg	3.59		3.49		3.49	
Means (of 16)	Ca	6.86		7.84		7.21	
	K	1.66		2.73		4.41	
	Mg	3.77		3.55		4.69	
Means (of 8°)	Ca	A 6.81	B 6.91	A 7.95	B 7.74	A 8.25	B 6.18
	K	A 1.75	B 1.08	A 3.21	B 2.25	A 6.29	B 2.52
	Mg	A 3.91	B 3.63	A 3.49	B 3.63	A 4.65	B 4.72
L.S.D.s	Ca	2 means of 16		2 means of 8†		2 means of 8°	
	K	0.60*	1.61***	0.85*	1.33**	0.76*	1.15**
	Mg	0.82*	—	1.16*	—	1.07*	1.65**

The significant influence of the treatments on exchangeable soil calcium has been confined to the differential effect of mulch + cattle manure vs. cattle manure, i.e. A. vs. B. for this particular treatment. The combination of mulch and cattle manure on two sides of the tree has increased significantly the exchangeable soil calcium over the cattle manure alone. This may be only a fortuitous difference since overall mean values for mulch + ammonium sulphate and mulch + cattle manure treatments are higher than the control treatment but do not themselves differ greatly.

Exchangeable soil magnesium values have been increased significantly by the mulch + cattle manure treatment, an effect attributed largely to the cattle manure (ref. Table LVIII), and one which is most noticeable in the 0-6 in. soil sample. This is also substantiated by the fact that there is no appreciable difference between samples taken from the inter-row space A, mulch + cattle manure, and the tree row space B, cattle manure only.

The most pronounced treatment effects are undoubtedly those found in the exchangeable soil potassium data. Overall, mulch + ammonium sulphate, and to an even greater extent the mulch + cattle manure treatments, have increased these values in the topsoil. Cattle manure applied to a mulched (Napier grass) soil surface has more than doubled the soil exchangeable potassium compared with mulch alone and quadrupled the control, no soil cover, values in the topsoil sample. However, the presence of a mulch cover, and consequently greater downward movement of soil moisture, would seem to be essential for appreciable increases to occur at a depth of 18-24 in. following cattle manure applications.

Two major conclusions may be drawn from these data, namely (i) that mulching will produce an uneven degree of soil fertility build-up (i.e. mineral addition) around a tree when it is confined to the inter-row space, and (ii) that the application of Napier grass mulch or of Napier grass mulch + cattle manure (considering the data of both Tables LVIII and LIX together) will flood the soil with substantial quantities of available potassium in the upper two feet of the soil profile, whereas the values for calcium are little affected and available soil magnesium only increased appreciably by the cattle manure.

This effect of Napier grass mulch must be considered as largely responsible for the increase during recent years of visual magnesium deficiency conditions, particularly when considered alongside steadily rising crop yields. The overall soil ratio of exchangeable magnesium to exchangeable potassium for the unmulched, control treatment is about 2.3 : 1, for mulch + ammonium sulphate it is about 1.3 : 1 and for mulch + cattle manure it is about 1.0 : 1. The antidote would seem to lie in the application of magnesium fertilizer to the soil and not in the discontinued application of organic mulches with their several advantages, although Napier grass could perhaps be replaced by a grass less rich in potassium.

An experiment with soil columns enclosed in plastic tubing was carried out in the greenhouse, to examine the differential effects on soil exchangeable potassium, calcium and magnesium, and on ammonium and nitrate nitrogen which might be observed between a control (no mulch) versus a Napier grass mulch (organic) and a shredded plastic mulch (inert) treatments when rainfall percolated through the column. The presence and absence of ammonium sulphate fertilizer at rates equal to field application was also included. Analyses of minerals lost in the drainage water and of the soil at the beginning and the end of the experiment were made. There were three replications of six treatments arranged in randomized blocks, and the experiment lasted for a period of three months.

A total quantity of water equal to 35 in. of rainfall was applied at a rate of one application per week. The 1-foot columns of soil were reconstituted on a volume/weight basis, from bulk field samples collected at 0-3 in., 3-6 in., 6-9 in., and 9-12 in.; the bulk samples were air dried and crushed gently to a moderately fine condition such that packing in the columns was facilitated. A summary of recorded data is given in Tables LX and LXI.

The plastic columns of soil were placed in a greenhouse and the surface of the columns was fully exposed to the sunlight. The outside of the plastic was painted to exclude light throughout the length of the column. Soil temperatures below 2-3 in. would be greater than under field conditions, and similar throughout the column.

The quantity of water moving through the column may seem excessively high, but it is not unduly so. From soil water balance studies carried out for purposes of irrigation investigations it would seem that during the long rains period as much as 20 in. of rainfall may pass through the top foot of the profile during a period of two-three months in very good years.

TABLE LX
Volume of applied water drained through the column and quantities of some minerals collected in the leachate from 1-ft. soil columns of a Kikuyu red loam coffee soil
(Means of 3)

Treatment	Vol. of water (inches)	NO ₃ -N lb./acre/foot	Potassium lb./acre/foot	Calcium lb./acre/foot	Magnesium lb./acre/foot
No mulch	21.4	192	258	140	68
Ammonium sulphate (S.A.)	21.2	228	278	175	85
Napier grass mulch (N.G.)	24.2	144	392	319	157
N.G. + S.A.	23.9	145	414	338	166
Plastic mulch (P.M.)	27.8	199	304	153	71
P.M. + S.A.	28.2	222	344	189	85
L.S.D.s 5%	0.33	11.3	6.6	10.6	4.8
1%	0.49	16.1	9.3	15.2	6.9
0.1%	0.77	—	13.5	21.8	9.9

More water passed through the plastic mulched columns (=80%) than through either the Napier grass mulched (=70%) or unmulched (= 60%) columns. This is believed to be a measure of relative mulch efficiency and the effect of hold up through adsorption by the Napier grass mulch with subsequently greater evaporation loss from the grass mulch than the plastic mulch.

The quantity of nitrate nitrogen lost from the unmulched and the plastic mulched columns, ± ammonium sulphate, was very similar whereas significantly less was lost from the Napier grass mulched columns although extra nitrogen was available from the mulch itself. In the unmulched and plastic mulched treatments, more nitrate nitrogen was lost from the ammonium sulphate treated than from the untreated columns but this was not so in the presence of Napier grass mulch. As greater nitrate or ammonia nitrogen residues were not found in the Napier grass mulched soil columns (see Table XXII), considerably more nitrogen must have been immobilized within the column by soil fauna as the result of increased activity, or lost in a gaseous form.

Greater quantities of potassium, calcium and magnesium were lost from columns treated with ammonium sulphate fertilizer irrespective of the type of mulch cover or whether unmulched. Much more of these nutrients were lost from the Napier grass mulched columns, largely as material leached from the Napier grass material and because more water passed through the column. This latter

TABLE LXI
Residual soil analysis of the soil columns (means of 12)

Treatment	NO ₃ -N ppm	NH ₃ -N ppm	Potassium (m. eq. %)	Calcium (m. eq. %)	Magnesium (m. eq. %)
No mulch	5.4	2.77	0.54	6.13	2.83
Ammonium sulphate (S.A.)	6.1	2.37	0.52	6.27	2.70
Napier grass mulch (N.G.)	4.2	3.57	1.57	5.92	2.74
N.G. + S.A.	4.9	4.63	1.54	6.13	2.87
Plastic mulch (P.M.)	5.6	3.21	0.69	5.95	2.66
P.M. + S.A.	4.3	2.82	0.62	6.02	2.73
L.S.D.s 5%	1.3	—	0.16	—	—
1%	—	—	0.22	—	—
Mean soil values before experiment	—	—	2.11	8.41	4.77

Notes: The values are means for the four sample depths, i.e. the columns were cut up again for analysis into 0-3 in., 3-6 in., 6-9 in. and 9-12 in. vertical intervals.

reason probably also accounts for the greater loss of these nutrients from the plastic mulched than from the unmulched columns. The influence of the ammonium sulphate fertiliser in facilitating greater leaching loss of these plant nutrients through the presence of the sulphate ion is well illustrated.

All treatments have left the soil with a lower available potassium, calcium and magnesium content when analysed one week after the last addition of water. About one-quarter to one-half of the exchangeable potassium, one-quarter of the exchangeable calcium and one-half of the exchangeable magnesium have apparently been lost and additions of these nutrients from the Napier grass mulch are only noticeable in the potassium figures. This suggests that all the extra calcium and magnesium derived from this source was lost through the 1-foot column. Exchangeable residual potassium was very significantly greater in the Napier grass mulched soil column; whereas nitrate nitrogen residues were less under Napier grass than under unmulched or plastic mulched soil columns. Ammonia nitrogen was greater, but not significantly so, under the Napier grass mulch treatment.

The direction of the changes which took place during this experiment, in exchangeable soil potassium, calcium and magnesium, are borne out by field soil sample analyses as reported previously. These are that Napier grass increases soil exchangeable potassium but has little permanent effect on exchangeable calcium or magnesium.

CHEMICAL CONTROL OF WEEDS IN COFFEE

Since 1953 investigations have been carried out with various chemicals for the control of weed growth in mature coffee. Results have been reported from time to time (9, 10, 11, 12, 13) and some degree of success has been obtained.

The problems to be overcome may be detailed as:—

- (i) to develop effective and economic spray control measures for mixed mono and dicotyledonous weedgrowth;
- (ii) to develop a specific control technique for couch grass (*Digitaria scalarum*) in coffee;
- (iii) to control weeds growing through organic mulches laid in the inter-rows and in the unmulched inter-rows. The latter problem is not so important because control is possible with modified rotovator cultivation during the rains.

Assessing the results of chemicals applied to control weedgrowth is carried out in the following ways:—

- (i) assessing the degree of weed kill obtained;
- (ii) observation for visible adverse effects of the chemical on the vegetative growth of the tree;
- (iii) by the assessment of coffee liquor quality in relation to chemical treatments and the detection of chemical taints in the liquor;
- (iv) by the influence of weed control on clean coffee yields.

The most promising chemical combination at first found for mixed weed control (excluding the permanent eradication of couch grass), in either mulched or unmulched coffee rows, was a mixture of pentachlorophenol and 2,4-D (14). Crop yields were increased significantly (+2.2 cwt. clean coffee per acre) following weed control with this mixture when the results were compared with no weed control during the Long and Short Rains seasons (11). It was subsequently shown that a "brickly" type of chemical taint could also develop following use of this mixture (11, 13) and no firm recommendation to the industry was therefore made.

Subsequently, a mixture of Dalapon plus 2,4-D proved, if anything, to be more effective in that couch grass could also be extensively controlled.

In early work at this Station (15) it had been demonstrated that T.C.A. at rates which would provide a practical control of couch grass seriously affected the coffee, producing severe defoliation and dieback following uptake from the soil. Current work suggests, however, that Dalapon can provide an economic and effective control of couch grass in coffee without harmful side effects on the crop. Dalapon is available to the industry and is used now for controlling localized outbreaks of couch grass by spot application of a 1.2% w/w solution in water. It has also been used in mature coffee at up to 10 lb. per acre against severe infestations with some degree of success.

New chemicals are being produced all the time for weed control and promising new materials are screened at this Station for their weed-killing ability and possible harmful effects on the coffee tree before being entered for more comprehensive trials.

A COMPARISON OF THREE TYPES OF PHOSPHORUS FERTILIZER ON THE KIKUYU RED LOAM SOIL

During 1955 a series of simple fertilizer trials were commenced to compare the efficiency of double superphosphate, basic slag and hyperphosphate reno (a French North African rock phosphate) fertilizers in terms of crop yields on the Kikuyu red loam soil. Three individual trials were started, each with a different crop, and they are being continued for a period of three years. Results to the end of the 1956 Short Rains crop period are summarized below.

Perennial Napier Grass (Pennisetum pupureum) for coffee mulching.

The previous history of the experimental site was that mature coffee had been uprooted prior to the Long Rains 1953. Thereafter a crop of silage maize was taken in the Long Rains 1953 and Napier grass was planted in the Short Rains 1953. No fertilizers or manure had been applied to the experimental area since 1947 within certain knowledge.

The layout consisted of three replications of eight treatments in the form of randomized blocks. All the phosphatic fertilizers are being tested in the presence and absence of nitrogen fertilizer. The phosphatic fertilizers were applied early in each Long Rains only, initially in a band along one side of the rows and subsequently broadcast over the Napier grass stools; nitrogen fertilizer was applied early in both the Long and the Short Rains in a band along the side of the row, the side being alternated in each rains. The plot size is 1/60th of an acre, and results are summarized in the following table as total yields of green material per acre for the four seasons, i.e. Long Rains 1955 and 1956, Short Rains 1955 and 1956.

TABLE LXII
Yields of Napier grass

<i>Nitrogen Treatments</i>	<i>Phosphorus Treatments (Tons Green Matter/acre)</i>				<i>Means (of 4)</i>
	(1)	Ps.	Phr.	Pbs.	
—N	68.29	79.61	73.50	84.68	76.52
+N	77.68	86.10	76.29	77.26	79.33
Means (of 2)	72.99	82.86	74.90	80.97	

Notes: 1. Figures in the body of the table are totals for three replications cut once at the end of each of four seasons.
2. Ps., double superphosphate (42-45% P_2O_5);
Phr., hyperphosphate reno;
Pbs., basic slag;
N, ammonium sulphate.

The ammonium sulphate is applied at a rate of 1 cwt. per acre per application, giving 2 cwt. per acre per annum; the phosphatic fertilizer rates are 100 lb. double superphosphate, 145 lb. hyperphosphate reno and 292 lb. basic slag per acre to provide (about) 42 lb. water soluble P_2O_5 , 42 lb. citric soluble P_2O_5 and 42 lb. citric soluble P_2O_5 per acre respectively.

Not one of the individual season's results for any single treatment produced a yield significantly greater than the control. Variation was high and it seems likely from the cumulative totals in Table LXII that an overall yield increase has resulted from the double superphosphate and the basic slag treatments and that in the absence of phosphatic fertilizer the nitrogen treatment has also produced a yield increase. The detailed statistical analysis of cumulative data will be completed at the end of 1957 when the experiment is finished.

Silage Maize (Long Rains) and White Haricot Beans (Short Rains).

(i) Maize Silage:

The layout for this experiment was exactly the same as for the trial with Napier grass described in the previous section of this report; plot sizes were 1/180th of an acre. Phosphorus fertilizer

treatments were also the same, applied to the Long Rains maize silage crop. The nitrogen treatment of 1 cwt. ammonium sulphate per acre was applied only to the Long Rains maize; no application of nitrogen was made to the Short Rains bean crop. The results for the 1955 and 1956 season are summarized in Table LXIII.

TABLE LXIII

Yields of Silage Maize (Means of 3)

<i>Nitrogen Treatments</i>		<i>Phosphorus Treatments (Tons Green Matter per acre)</i>				<i>Means (of 16)</i>
		(1)	Ps.	Phr.	Pbs.	
—N	1955	12.00	18.95	11.35	14.35	14.16
	1956	11.07	17.68	15.22	19.58	15.89
+N	1955	10.98	15.57	13.04	15.10	13.67
	1956	10.31	17.58	15.27	18.22	15.35
Means (of 6)	1955	11.49	17.26	12.19	14.72	
	1956	10.69	17.63	15.25	18.90	

Notes: 1. Figures in the body of the table are means of three replicates for each season.
 2. L.S.D.s for phosphorus fertilizers, means (of 6) (1955 figures) = 2.58*; 3.57**.
 3. For explanation of Ps., Phr. and Pbs. see footnote to Table LXII.

Although the control treatment yield was similar in both seasons, the phosphatic fertilizer effects were rather different. The quick-acting superphosphate produced a significant effect in both years, but the other two fertilizers, although they assisted in greater yield production in the 1955 season, produced an even greater response in the 1956 season. This applies particularly to the basic slag. Nitrogen seems to have had very little overall effect.

The relative yield responses to the three forms of phosphatic fertilizer are similar to those obtained with Napier grass in the experiment described in the previous section.

(ii) White Haricot Beans:

In the two Short Rains (1955 and 1956) white haricot beans were planted in the same plots as the maize silage crops were taken from. Responses of this legume to residual phosphatic fertilizers were measured and results for the two seasons are summarized in Table LXIV.

TABLE LXIV

Yields of White Haricot Beans (Means of 3)

<i>Nitrogen Treatments</i>		<i>Phosphorus Treatments (lb./acre)</i>				<i>Means</i>
		(1)	Ps.	Phr.	Pbs.	
—N	1955	153.1	180.5	185.8	210.7	182.5
	1956	362.0	504.6	445.1	519.7	457.9
+N	1955	166.4	199.4	162.5	209.8	184.5
	1956	422.4	490.5	424.3	413.0	453.5
Means (of 6)	1955	159.7	189.9	174.1	210.2	
	1956	392.2	497.5	434.7	466.3	

Notes: L.S.D.s for phosphorus fertilizers, means (of 6) (1955 figures) = 38.7*; 53.7**.
 L.S.D.s for phosphorus fertilizers, means (of 6) (1955 figures) = 90.2*; 125.1**.
 For explanation of Ps., Phr., Pbs. see footnote to Table LXII.

The response to the residual phosphatic fertilizer dressings have been marked in both seasons. Yields were low in 1955 because of a low total rainfall (approximately 5½ in.), a very small percentage of which was effective. The order of the fertilizer effectiveness is not so apparent as in the previous data, i.e. Napier grass and silage maize, but is of a similar pattern. Ammonium sulphate fertilizer has had no residual effect on yields.

Three blocks, each of a different grass species, were treated with the phosphatic fertilizers (at previously noted rates per acre) commencing in the long rains 1955. Replication of the controls plus these fertilizer treatments was confined to the three blocks and it was expected that only very large treatment effects would show up. The plot size was very small (1/222nd acre). As the grasses were planted in 1950 and had been cut regularly twice a year since then, large responses were in fact expected. No manurial treatments were applied at the time of planting nor since that time.

TABLE LXV
Yields of Pasture Grass Species (Tons green matter per acre)

<i>Treatments</i>	<i>L.R.'55</i>	<i>S.R.'55</i>	<i>L.R.'56</i>	<i>S.R.'56</i>	<i>Totals</i>
(1)	5.46	4.76	3.63	3.92	17.77
Ps.	5.16	3.94	3.76	3.46	16.32
Phr.	5.66	5.09	4.68	4.99	20.42
Pbs.	4.56	3.44	3.94	4.11	16.05

Notes: Grass species are *Panicum maximum* var. *trichoglume*, *Bothriochloa insculpta* and *Setaria* sp. ex Nandi.
L.R. = Long Rains and S.R. = Short Rains.
For explanation of Ps., Phr. and Pbs. see footnote to Table LXII.

The fertilizer treatments were applied in the Long Rains of each year and were broadcast between the rows. Hand cultivation was carried out after each rains when the grass had been cut. It had not been intended to apply ammonium sulphate in this trial but the pale green-yellow condition of the foliage during the Long Rains 1955 prompted a blanket application of 1 cwt. per acre in the following Short Rains. This has since been repeated in the Long Rains 1956.

No individual season responses have been recorded, and data for cumulative statistics are not complete. It is remarkable, however, to note the apparent cumulative response to the hyper-phosphate-reno (Phr.) treatment where hitherto this fertilizer has provided the least response in the other crops tested. Although the data are not reported here in full, there has been no specific response of any particular grass species to the treatments.

CULTIVATION AND CROPPING OF VLEI SOILS

In 1954 an experiment was started on this Station to study the utilization of vlel land for arable farming under a system of camber bed cultivation. The object was to make more land available on coffee estates for the production of coffee mulch grasses.

The system of cultivation has been described and early yield results for indicator crops and Napier grass given (18, 19, 20). A 2³ factorial fertilizer and manure experiment with three replications was laid down when cultivation was completed. The plot size is 1/60th acre. After a Long Rains yellow maize crop and a Short Rains white haricot beans crop in 1954 Napier grass was planted with the Long Rains 1955. Results to the end of 1956 are noted together with treatments in Table XVI.

The recorded yields were obtained after camber bed cultivation of the vlel soil. Flat ploughing and subsequently flat cultivation was not examined experimentally because past experience has shown that consistent crop failure results from waterlogging (perched water table) conditions during wet seasons and very fast drying out of the shallow friable topsoil when the rains are over. Prior to the introduction of camber bed cultivation there was virtually no arable cropping of vlel lands and only sporadic grazing or cutting of grasses after the rains was undertaken over these areas.

TABLE LXVI

Summary of Crop Yields from Camber Bed Trial on Vlei Land

Treatment	Yellow Maize L.R.'54		Beans S.R.'54		Napier Grass							
					L.R.'55		S.R.'55		L.R.'56		S.R.'56	
	A	B	A	B	A	B	A	B	A	B	A	B
(1)	3.2	—	0.36	—	1.91	—	7.78	—	8.68	—	5.06	—
N	6.9 + 1.9	—	0.39	—	2.92	—	9.58 + 2.72	—	10.90 + 7.51	—	6.27 + 1.58	—
P	7.9 + 3.1	—	1.90 + 1.07	—	8.64 + 7.05	—	11.11 + 4.47	—	11.42 + 6.20	—	7.04 + 2.25	—
C	15.6 + 10.2	—	1.28 + 0.50	—	7.74 + 4.98	—	13.60 + 4.80	—	14.82 + 5.34	—	7.69 + 2.34	—
NP	9.3	—	1.62	—	9.70	—	16.81	—	24.86 + 3.96	—	9.80	—
NC	15.8	—	1.10	—	6.57	—	14.99	—	19.71	—	9.32	—
PC	17.1	—	1.83 — 0.32	—	14.05	—	16.92	—	16.58 — 2.14	—	9.90	—
NPC	19.4	—	2.05	—	14.74	—	18.97	—	26.09	—	10.63	—
L.S.D.s												
5%	—	2.17	—	0.20	2.17	—	1.64	—	3.69	1.84	2.43	1.21
1%	—	3.04	—	0.28	2.97	—	2.27	2.30	5.12	—	3.37	1.68
0.1%	—	4.20	—	0.39	—	2.06	—	3.19	—	3.56	—	—

- Notes: 1. A = mean treatment yield over three replications;
B = yield effects over all treatments, means of 12.
2. L.R. = Long Rains period; S.R. = Short Rains period.
3. Yellow maize and bean yields in 200-lb. bags per acre; Napier grass yields in tons green material per acre.
4. N treatment is sulphate of ammonia applied at a rate of 2 cwt. per acre in L.R. '54 and S.R. '54; 1 cwt. per acre in each of the L.R. '55 and '56 and S.R. '55 and '56.
P treatment is double superphosphate (42-45% P_2O_5) applied at a rate of 1 cwt. per acre in each of the Long Rains periods, i.e. L.R. '54, '55, and '56.
C treatment is cattle manure (long) applied at a rate of 20 tons per acre in L.R. '54 and 10 tons per acre in L.R. '55. No application was made in L.R. '56.

Maize and bean crops were planted initially in this work as indicator crops, both of gross mineral deficiency and/or toxicity conditions. Neither crop provided visual leaf deficiency symptoms other than nitrogen and phosphorus in the control plots planted to maize and Napier grass and in the minus nitrogen and minus phosphorus plots respectively, the latter where no cattle manure was applied. Except for nitrogen, all responses in Short Rains crops are to residual fertilizer and manure applications. Low yields for the Long Rains 1955 Napier grass crop is because this was the first (post-establishment) cut.

Overall, responses have been obtained in the Napier grass crop to nitrogen and phosphorus fertilizers and to cattle manure, the latter two treatments providing both direct and residual effects. Double superphosphate fertilizer greatly assisted the establishment of the Napier grass followed by the cattle manure, ammonium sulphate did not have a very large effect, but the phosphorus fertilizer plus the cattle manure together increased the first cut substantially.

In practical terms, and assuming a parallel set of yield responses under vlei soil conditions generally in the coffee area, good quality cattle manure alone or nitrogen plus phosphorus fertilizers together will make up the major shortages of plant foods to the extent that economic returns are obtained with Napier grass. It is equally apparent, in terms of Napier grass mulch production, that camber bed cultivation of vlei land is hardly going to be an economic proposition without the use of one or the other of these alternative practices. It should be pointed out that in this trial the highest yields were obtained to the application of both the fertilizers together with cattle manure.

Under field conditions it is likely that urea fertilizer could be used in the place of ammonium sulphate, and basic slag in the place of double superphosphate, but at modified rates of application per acre.

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PLANT PHYSIOLOGY GROWTH RECORDING EXPERIMENTS

Research on the physiology of coffee has been carried out by the same investigator responsible for plant pathological work since 1939. With the expansion of the Coffee Services it has become increasingly obvious that research on physiology should be allotted a separate section headed by a plant physiologist. Although several years ago a post of plant physiologist was created, the position was not filled. Then, with the threat of increasing depredations due to Coffee Berry disease, a temporary arrangement was made by which one member of the research team for this disease occupied the post. With the decision to increase coffee research made earlier this year, it has been possible to create a further post for a plant physiologist. In view of this decision, the Plant Physiology and Pathology section has concentrated on pathological investigations during the past year and only those physiological investigations already in being have been maintained. These consist largely of growth recording investigations and the Maleic Hydrazide Trial.

Growth Recording

Growth recording has now been carried on for 16 years, having been commenced in late 1941 at the Scott Laboratories. Records have continued in varying form since, consisting essentially of measuring the lengths of a number of branches at intervals, usually two weeks, and from these measurements obtaining the rate of elongation. At the same time the number of nodes present on each branch is recorded and the rate of addition of new nodes obtained.

The first series of observations at the Scott Laboratories was carried out on a group of nine single-stem, Kenya Selected trees, three of which, in one block, were irrigated from June, 1942, onwards. Sixteen branches were recorded for growth on each tree. Various additional data were recorded at various times and for various periods, e.g. numbers of flowers, numbers and weight of crop, numbers of branches per tree, soil moisture, etc.

In brief, the main results of this series of observations were as follows: There were two growth periods in each year, corresponding to the two rainy seasons. The Long Rains growth period was normally the most marked, but occasionally the Short Rains growth would be more marked. This seemed to be determined by whether there was a heavy crop, the amount of rain and the amount of growth in the Long Rains. In many seasons, the amount of growth in the two growth periods was closely correlated with rain and not necessarily with soil moisture, suggesting atmospheric humidity as an important factor. In seasons of heavy rain, growth would slow up before the rains ceased, perhaps due to decreasing soil nitrogen supplies. Increasing density of foliage may also have played a part. Maintaining soil moisture by irrigation had relatively little effect on the general pattern of the growth curves except in the first two years; though the amount of variation from year to year was reduced the overall rate of growth was higher. Flowering tended to have a more regular pattern of heavy Long Rains and small Short Rains bursts, whereas cropping was heavier and varied less from year to year.

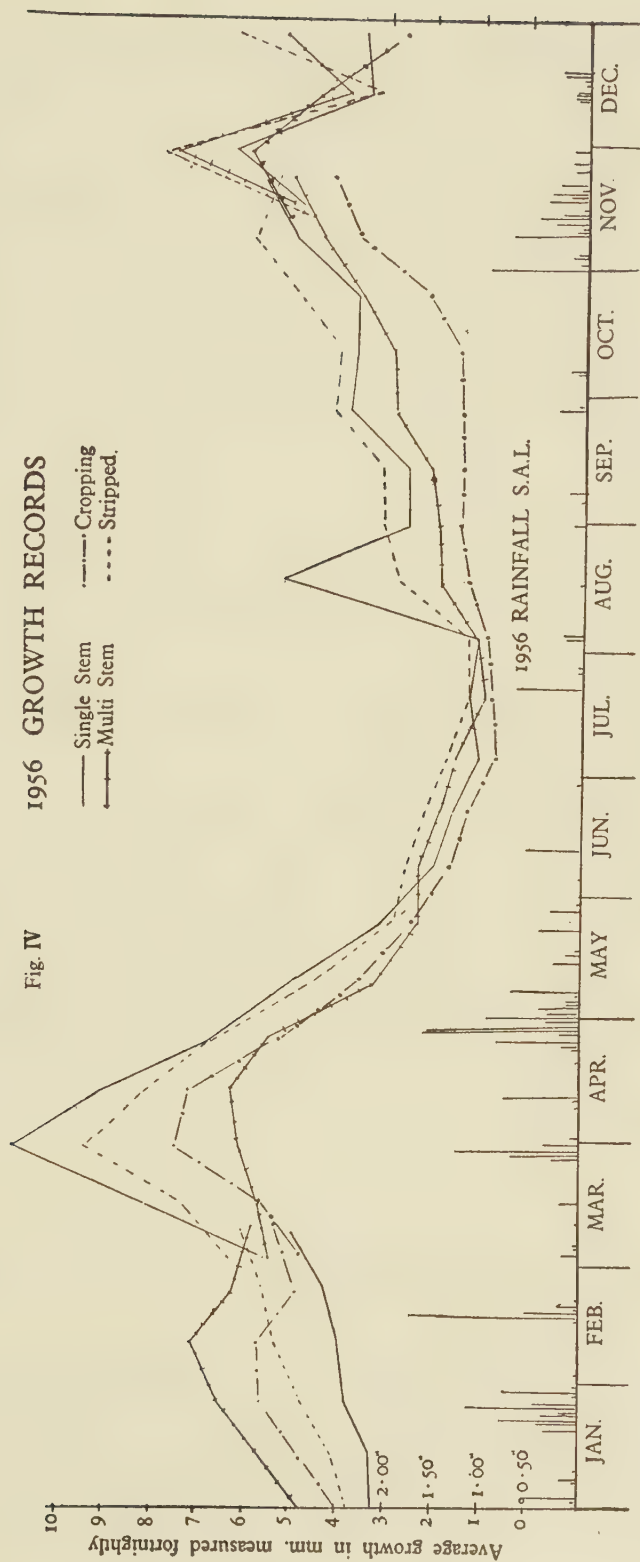
The lack of effect on the growth pattern of the irrigation treatment led to the initiation of two further experiments, one at the Scott Laboratories and one at the Coffee Research Station as described below.

The Growth Recording Experiment at the Scott Laboratories, Nairobi

This is of a single 2^2 factorial design contrasting multiple-stem and single-stem pruning in combination with stripped and cropping trees. There are two trees per plot and four plots per block in three replications. On the stripped trees, crop is removed soon after flowering. The altitude is 5,700 ft. and the coffee is Kenya Selected. The average rainfall (ten years) is 35.33 in. Growth is recorded on four branches per tree, one chosen at random in each of the four quarters. Recording started in February, 1952, on the single-stem trees, and on the multiple-stem trees when conversion was completed in March, 1954.

The general picture of a strong Long Rains growth period and a less marked Short Rains growth period, separated by periods of minimum growth, prevailed during the years 1952-1956. In 1956, however, the Short Rains growth period was fairly strongly marked, though still considerably less

Fig. IV 1956 GROWTH RECORDS



than the Long Rains growth of that year. The most remarkable growth phenomenon during the period was the early onset of growth in the years 1952, 1955 and 1956. In the latter two years this was associated with heavy rain in February, 1955, and in January—February, 1956. In 1952 it was attributed to the heavy rain of 1951, especially during the Short Rains period, which provided a high reserve of soil moisture during the warm weather which followed.

None of the treatments had any very marked effect on the general shape of the growth curves. On the whole, stripping was associated with a higher growth rate, especially during the Short Rains. In the Long Rains the effect was slight and in some years (1953 and 1954) the stripped trees grew less at this time, perhaps a compensatory effect. There was little difference between the growth of the two pruning systems, multiple stem tending to grow more rapidly than single during the Short Rains. This tendency was enhanced by stripping.

In 1956, presumably in response to the heavy unseasonal rains of January and February, a good proportion of the Long Rains growth had occurred before the Rains proper broke at the end of March. This was more marked with multiple-stem trees than single stem. With the early cessation of the Rains growth fell away rapidly to a very low level during June, July and August, to build up gradually to a low peak in November.

It is evident from these results that neither cropping level nor pruning system alone or in combination have more than minor effects on the general shape of the annual growth curve.

The Growth Recording Experiment at the Coffee Research Station, Ruiru

This experiment has broader scope than its counterpart at the Scott Laboratories and consists of a 2³ factorial design with two replications, the main plots being split for the effect of crop stripping. The main treatments are single- and multiple-stem pruning, artificial shading and no shading, irrigation and no irrigation.

The plots contain eight trees, but only four are used for growth recording; the remainder are used for nutrition investigations, crop estimates, etc. Two guard rows surround each plot, the trees adjacent to each being pruned on the same system as the plot.

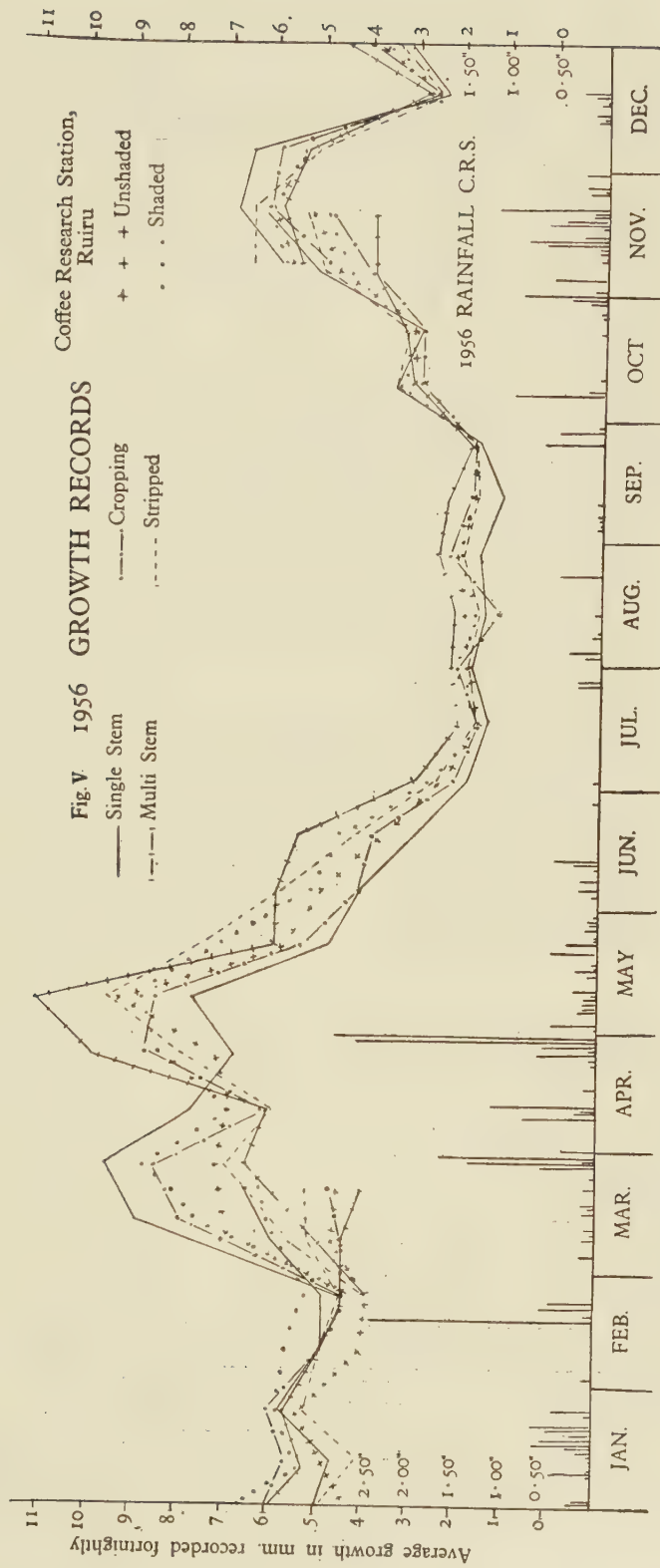
All the trees started as single stem, conversion of those destined to be multiple stem starting at the commencement of the experiment, when only the single-stem trees were recorded for growth. Records were first taken as follows: single stem—March, 1951, multiple stem—March, 1954. Irrigation was commenced in January, 1955, plastic pipes running along the coffee lines 6 in. above ground level being used. These had holes bored at intervals which were arranged so as to produce a number of jets of water impinging on the soil in a pattern which produced an adequate distribution of water around the trees. The amount of water applied to each plot was measured by a water meter and recorded. Unfortunately, water pressure fell soon after installation of the system and irrigation had to be discontinued until the end of December, 1956. The aim is to avoid any marked deficiency of water in the soil and the amount applied is related to the calculated water deficiency.

Artificial shade was erected in May, 1955. It consists of 2 in. wide aluminium strip threaded through 2 in. mesh wire netting leaving a 2 in. gap between each strip. The whole is supported 12 ft. above the ground on cedar posts and is allowed to hang down 4 ft. at each end of the plot to shade the trees from the morning and evening sun. The plots are two trees wide and their long axes run approximately N.W. to S.E. The shade extends laterally to a line midway between the guard and the plot trees.

The altitude is 5,400 ft. and the average rainfall (ten years) is 36.18 in.

As at the Scott Laboratories, there are two growth periods each year corresponding to the two rainy seasons and separated by periods of minimum growth. The Short Rains growth period is the lesser, but is more marked than at the Scott Laboratories; both growth periods tend to produce much sharper peaks of shorter duration.

Again as at the Scott Laboratories, in the years 1955 and 1956, growth started before the onset of the Long Rains proper, being associated with the unseasonal rains which fell in the early months of those years. In 1955, after heavy rain at the beginning of February, growth commenced and ascended to a peak at the end of the month and then gradually subsided. A considerable proportion of the Long Rains growth had thus occurred before the Long Rains proper broke in the third week of March. The position was similar in 1956, with heavy rainfall in both January and February. Growth ascended to a medium level during these months and rose to a peak early in May, dropping to a low level from



July to September. There was a small but marked Short Rains growth period with a peak in November.

As in the other trial, none of the various treatments had more than a minor effect on the general pattern of the growth curves. Similarly the absence of crop was usually associated with an increased growth rate, but this was generally least marked during the maxima of the growth periods and most marked during the July to September growth minimum. Since the maximum amount of developing crop is on the trees at this time this is to be expected. Occasionally during the Rains, the stripped trees grew less than the cropping ones, and almost invariably this was so during the January—February minimum growth period. Generally crop stripping exerted similar effects on trees of both pruning systems. In the Long Rains of 1956 stripping tended to lead to a reduced rate of growth of single-stem trees, but to an increased growth rate of multiple-stem trees. These effects were exaggerated by shade usually.

On the whole, multiple-stem trees tend to have a higher growth rate than those on single stem, but the relative rates are strongly affected by both season and year. Thus, in the Long Rains of 1954, multiple-stem trees had a higher growth rate than single, whereas the reverse was the case in the Short Rains. In 1955 there was little difference between the two in the Long Rains, but multiple trees showed a higher rate in the Short Rains. In 1956 there was a marked difference in the general growth pattern: maximum growth of multiple-stem trees preceded that of single stem by six weeks. These differences are uncommon but there was another instance at the end of 1955 when the Short Rains growth peak occurred early in January, about 11 weeks later than single-stem or shaded multiple-stem trees. In the same year the Long Rains growth of stripped multiple stem extended into June, when growth of other treatments was decreasing rapidly.

As irrigation was only applied for a short spell in 1955 there was little if any effect of this treatment, though there was a slight indication of increased growth rate during the Long Rains of that year to be followed later by a decreased rate.

Although no treatment has yet had a very marked effect on growth rate, shading produced, at an early date, a considerable effect on the appearance of the trees. The leaves are larger and darker green and the internodal distances are greater. Lateral branches are fewer and the trees have a more "open" appearance. Multiple-stem trees grow upwards more quickly and this will eventually shorten the cycle. Crop stripping has had less effect on the appearance of the trees than might have been expected. Yellowing and overbearing die-back was naturally absent, but a slight degree of yellowing, especially along the margins of the leaves, still occurred.

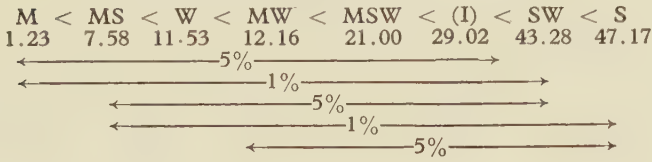
In 1956 crop was measured for the first time. As the aim was eventually to relate crop to growth and not to determine the commercial value of any of the treatments, only cherry weight was recorded. The results are recorded in Table LXVII and illustrated in Figure VI.

TABLE LXVII
Crop from Growth Recording Experiment, Coffee Research Station, 1956
(Cherry: lb. per 8 trees)

	<i>Multiple Stem</i>	<i>Single Stem</i>	<i>Total</i>
Unshaded, Unirrigated	1.23	29.02	30.25
Unshaded, Irrigated	12.16	11.53	23.69
Total : Unshaded	13.39	40.55	53.94
Shaded, Unirrigated	7.58	47.17	54.75
Shaded, Irrigated	21.00	43.28	64.28
Total : Shaded	28.58	90.45	119.03
Total : Unirrigated	8.81	76.19	85.00
Total : Irrigated	33.16	54.81	87.97
Total	41.97	131.00	

Significance of differences. Overall treatment effects significant at 5% level.

Symbols: M = multiple (absence = single).
 S = shade (absence = no shade).
 W = irrigated (absence = no irrigation).
 (1) = single, unshaded, unwatered.

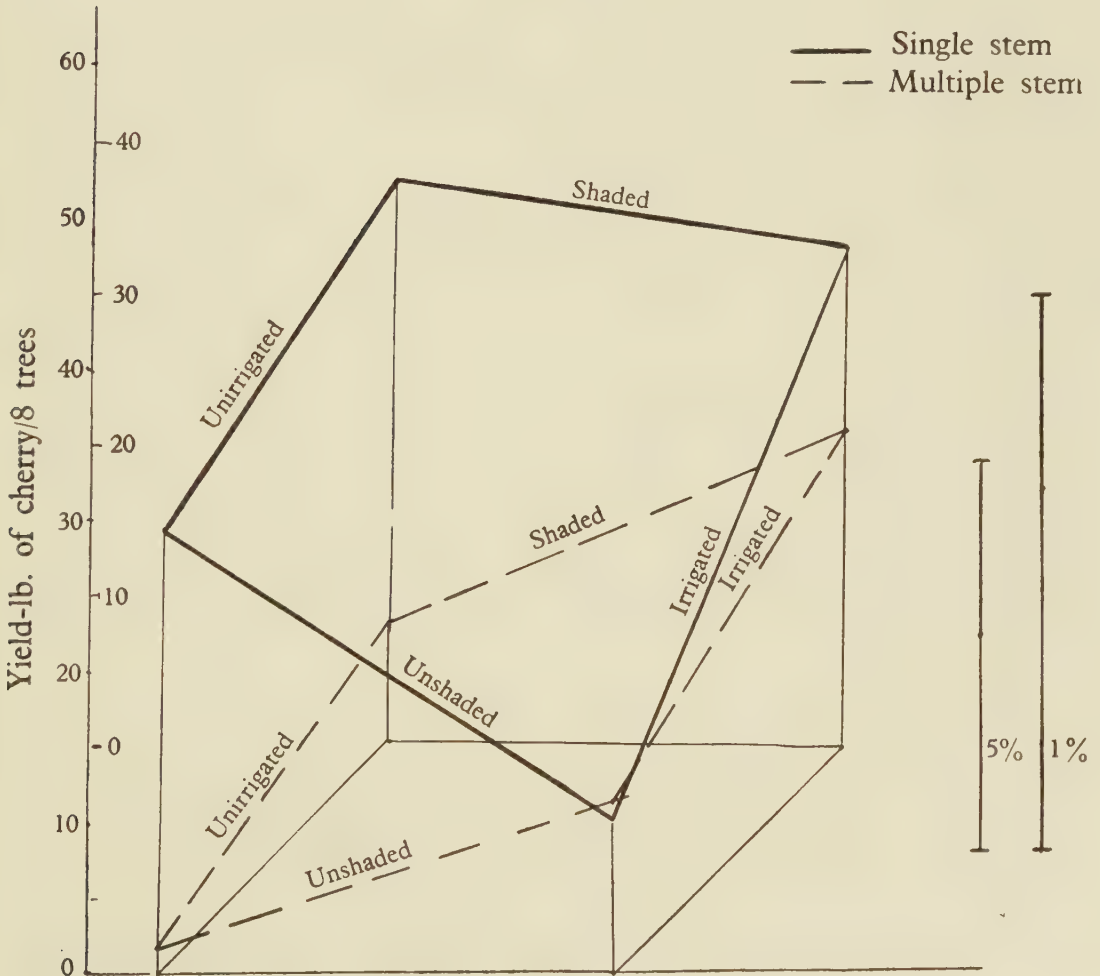


Multiple < Single 1% point.

No Shade < Shade 5% point.

1956

FIG. VI Three-dimensional graph showing the effects of pruning system, shade and irrigation on yield in the Growth Recording Experiment, Coffee Research Station, Ruiru.



Although the crop was small the effects of the treatments are quite marked and the overall effect was significant at the 5% level. Single stem yielded higher than multiple stem except at one treatment combination (unshaded, irrigated), the effect being significant at the 1% point. In every case the shaded coffee yielded heavier than the unshaded, the effect being significant at the 5% level. The difference was greater with single- than multiple-stem coffee.

Irrigation appears to have had some rather peculiar effects, although it was applied for only a short period—February, 1955, i.e. the previous year. As the effect on single stem was a depression in yield, it is possible an increase of crop may have resulted the previous year, when it was not recorded, and so the following year a reversal has occurred in compensation. In multiple stem, on the other hand, irrigation increased the crop slightly. There was no overall effect of irrigation, as the two pruning systems were affected in opposite ways. The interaction of irrigation and pruning just failed to attain significance however.

Some General Conclusions

It is not fitting in this report to specify the detailed conclusions which may be drawn from the extensive growth record data, but a summary of the predominant findings is appropriate.

The two Stations, at which detailed growth records have been made, can be regarded as typical of the greater part of the main East Rift coffee-growing area, the Scott Laboratories representing the upper and cooler areas, the Coffee Research Station the lower and warmer zones. To what extent Upper Kiambu is represented by the former, however, is doubtful; further observations should be made in this area.

At both Stations the annual growth cycle may be considered to consist of four distinct periods:—

1. A minimum growth period in the first months of the year, which are normally hot and dry. If rain falls at this time the period is liable to be considerably shortened.
2. A maximum growth period rising to a peak early in the Long Rains, or even before then if unseasonal early showers occur (as in 1955 and 1956). The growth rate usually falls off slowly with the onset of dry weather, and sometimes whilst there is still abundant soil moisture.
3. A minimum growth period of rather long duration from June to September. The first half is usually cool and cloudy. It may be dry throughout the period or available soil moisture may be present in the early part. The second half is usually dry and warmer.
4. A maximum growth period usually less marked than that in the Long Rains and associated with the Short Rains.

The main points of interest in this pattern are the minimum growth periods and their causes, especially those of the second one, and the reason for the sharp ascent to a peak in the Long Rains followed by a gradual decrease in growth rate even when available soil moisture is present. The first growth-recording experiment at the Scott Laboratories demonstrated that available soil moisture throughout the year did not appreciably influence the minimum growth periods of bearing trees. The Ruiru experiment has shown that they are not due to the demands of the crop, except to a rather minor degree. The effect of the combination of irrigation and removal of crop will be seen in 1957. An analysis of temperature effects, made a number of years ago, indicated that low temperatures were partly responsible for minimum growth at this time but were not the main factor. No subsequent observation has disproved the hypothesis formed then that this factor is probably air humidity. Thus it is considered that the reasons for minimum growth during July—September are probably several and include developing crop, cold and low available soil moisture, but that low air humidity may well be the main causal factor.

The principal factor producing the observed rapid increase to a peak at the beginning of the rains and the subsequent slow decrease, even when, otherwise, climatic factors appear favourable to continued active growth, may be supply of soil nitrogen. It has been known for some time that a flush of nitrate formation occurs at the onset of the rains and recent work by the Agricultural Chemist, Coffee Services, has shown that this flush is very strong and is followed by a very definite decrease in nitrate formation. Apparently baking of the soil must precede the flush of nitrate production. The evidence points to dependence of the Long Rains growth rate on the soil nitrate available to the tree. In consequence a co-operative experiment was undertaken with the Agricultural Chemist to observe the effect of nitrogenous fertilizers on this flush.

The experiment is described in the Chemistry section of this report. It is clear from the results that the addition of nitrogenous fertilizers broadens the Long Rains growth peak and lessens the

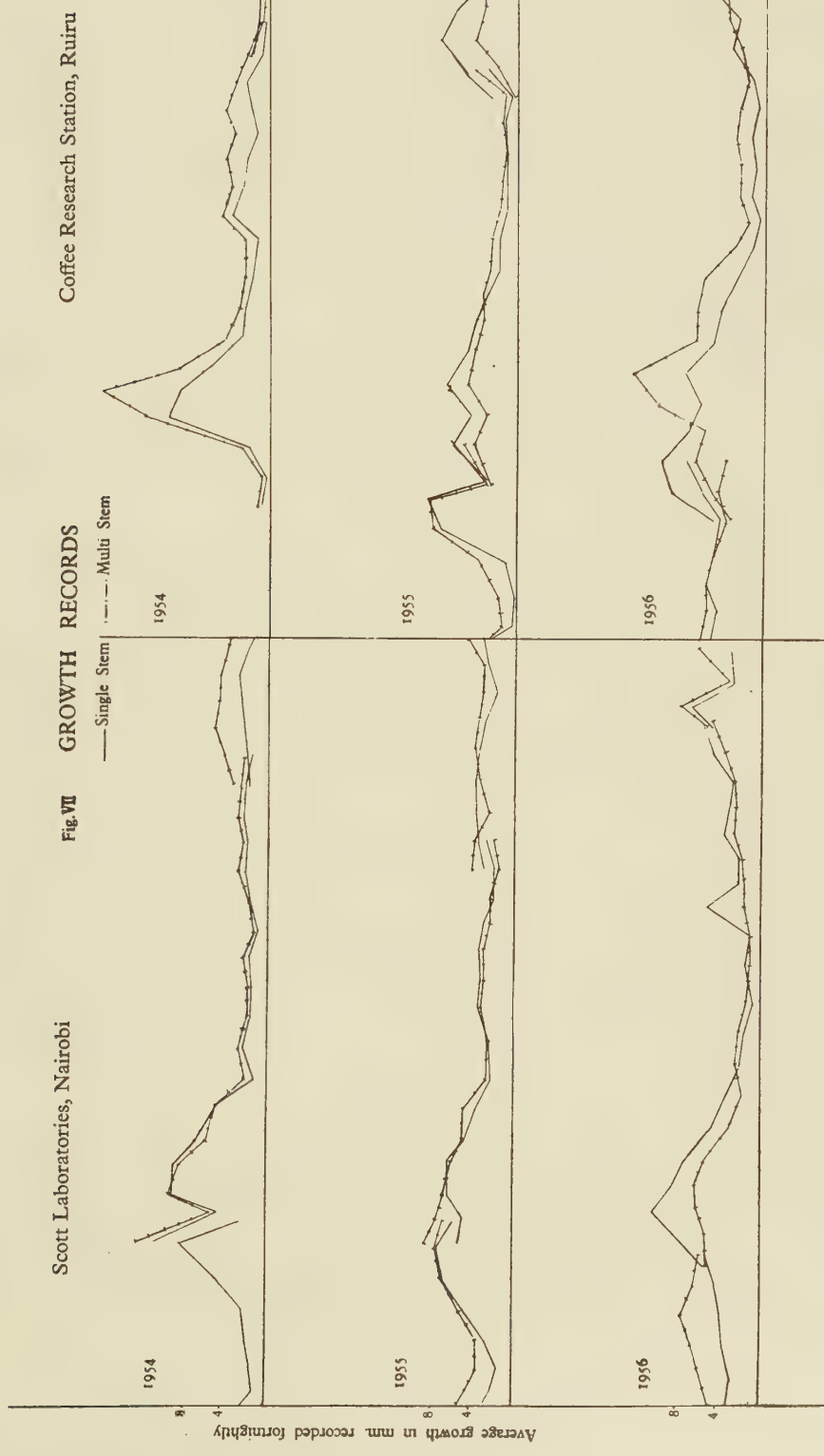


Fig. VII GROWTH RECORDS

Scott Laboratories, Nairobi

Coffee Research Station, Ruiru

— Single Stem
- - - Multi Stem

Average growth in mm. recorded fortnightly

subsequent decline. Thus it is confirmed that the shape of growth curve during the Long Rains is influenced by soil nitrogen.

TRIAL OF MALEIC HYDRAZIDE

In the West Rift coffee-growing areas yields tend to be considerably lower than in the East Rift. In part, the reason for this would appear to be physiological. There seems to be a general difficulty in inducing strong flower bud formation; much of this, even when present, may fail to produce flowers and the young fruit tends to be shed at an early stage. Moreover, the size and weight of the beans produced tend to be low. The most obvious difference in climate between the West and East Rift is the single long rainy season a year of the former as against the two shorter rainy seasons of the latter. There is thus only one resting period each year when conditions are contrasted to those of the rainy season (i.e. a severe drought). It may be inferred that vegetative growth is encouraged during the long rainy season and there is little opportunity for starch to accumulate. If this is so, flower initiation development suffers: there is competition for starch supplies between the developing fruit and vegetative growth and the former suffers. This would account for the various phenomena mentioned above.

If vegetative growth could be checked in the second half of the rainy season, starch reserves might be accumulated instead of being used up directly by fresh vegetable growth: consequently, both flower bud initiation and fruit development might be improved. Maleic Hydrazide is a substance which reduces vegetable growth. In preliminary tests it was found to be effective on coffee. Further, it appeared to reduce vegetative growth without affecting photosynthesis. Although background physiological work to confirm the ideas propounded above was lacking, evidence from other crops was favourable enough to justify an experiment to see if treatment with Maleic Hydrazide would increase flowering and fruiting.

A site was chosen on "Riverglade Estate" in the Western Cherangani area, near Kitale. Inadequate flowering has long been experienced in this area. This site was not ideal, because the growth rate was known to be rather low for the West Rift area, due probably to the rather cool conditions. The coffee is multiple stem and has a shade of *Grevillea robusta* trees. Sprays of Maleic Hydrazide were applied at 0.2% and 0.6% active ingredient in water. In the first year "Hydropal" was used—a Universal Crop Protection product—consisting of a solution of the triethanolamine salt of Maleic Hydrazide. A wetter, Agral L.N., was added. In the second and third years, Malazide, a sodium salt of Maleic Hydrazide, was used. One pint of spray was applied per tree. Three times of spraying were tried: July, August and September. In 1954 the sprays were applied about the middle of these months, whereas in 1955 and 1956 they were applied in the first week. The inclusion of a control gave seven treatments in all. A simple randomized block layout, with four replications and single line plots of 12 trees, was employed.

Growth was measured at fortnightly intervals in the same manner as in the growth-recording experiments described in the previous section. One branch chosen at random on each of the first three trees in each plot was recorded.

Crop was weighed as cherry, a 10% sample taken and processed through to clean coffee. The percentage of Grades A and B beans and the weight of 500 beans were determined.

Flowering was estimated by scoring the individual trees on a scale 0—5 on several occasions. Many of the flowerings were too sporadic to estimate. A count of the number of suckers on the first five trees on each plot was made on May 13, 1955.

The experiment had to be concluded in March, 1957, as considerable damage had been caused to the trees when the shade trees were felled. Further, the crop prospects were poor and the stronger sprays were having a very adverse effect on some of the trees.

Effects on Growth

The highest growth rate throughout was shown by the control plots. This showed a somewhat low level from the beginning of recording in August, 1954, until the Rains broke in April, 1955, when it ascended to a sharp peak in the first week in May and then fell precipitously to a low value at the beginning of July. From then on it ascended to a medium value until the end of the year. It descended to a low level in January and ascended to another marked peak in April. It again descended abruptly to a medium level during June to September, at the end of which month a low level was reached. A marked peak occurred in December. In February, 1957, a low rate had been reached from which another rapid ascent to a peak occurred in March.

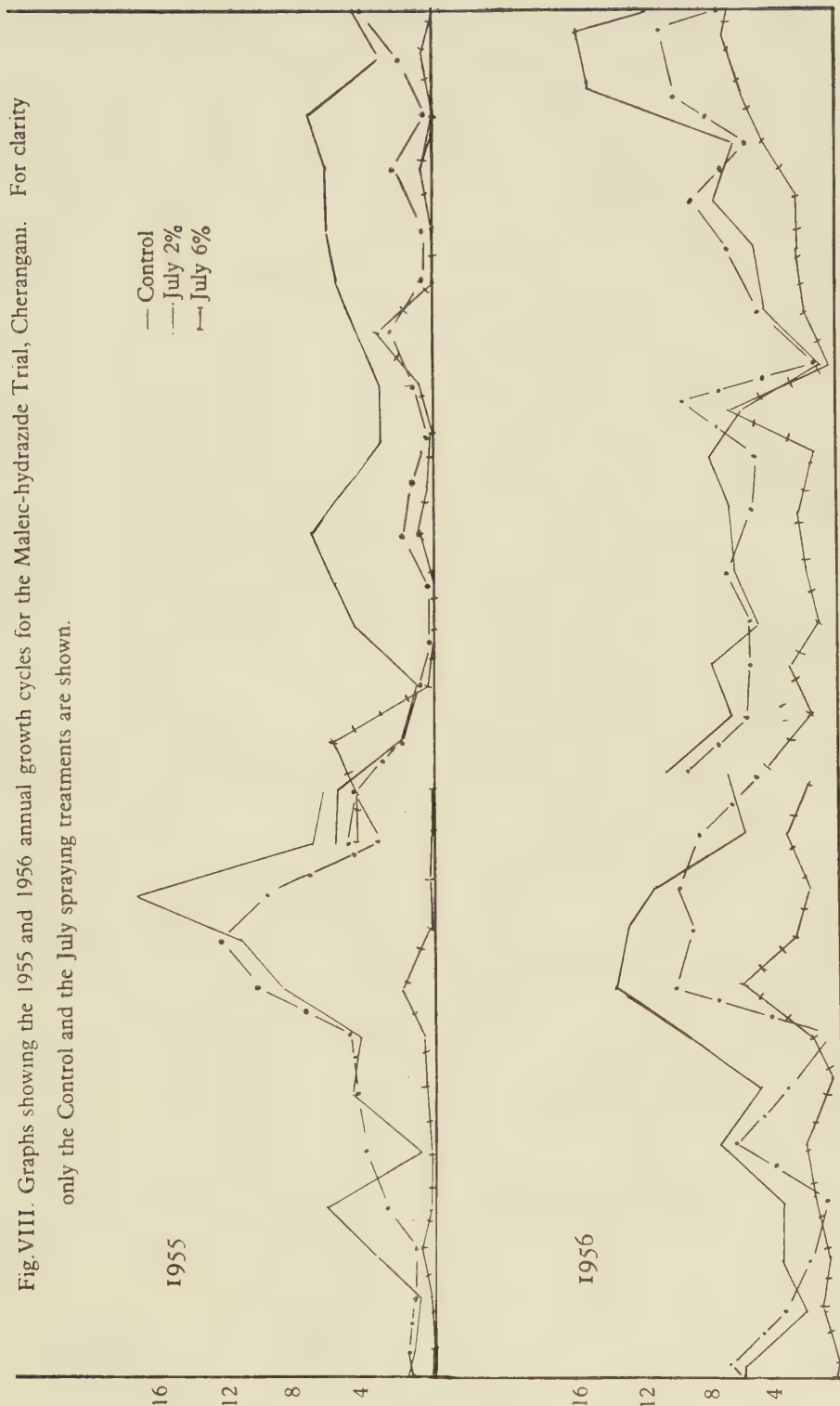
Fig. VIII. Graphs showing the 1955 and 1956 annual growth cycles for the Maleic-hydrazide Trial, Cherangan. For clarity only the Control and the July spraying treatments are shown.

— Control
 ···· July 2%
 —+— July 6%

1955

1956

Average growth recorded fortnightly in mm.



The shape of the growth curve is most interesting as it had always been supposed from the relative internodal lengths that growth under the West Rift rainfall régime would be fairly even during the rains. The extraordinary peaks produced by rain following a dry period are extremely interesting and bring to mind the bursts of nitrate production which have been found to occur in other areas at these times. In fact there is considerable resemblance between the growth pattern observed and that of the Long Rains growth flush in the East Rift. It would seem likely that nitrogenous fertilizers applied about a month and two months after the start of the rainy season might help to broaden the growth peak and thus produce a greater amount of mature wood and foliage for the next year's crop.

The total amount of growth has been calculated for half-yearly intervals and analysed statistically. The results are given in Table LXVIII.

TABLE LXVIII. RESULTS OF STATISTICAL ANALYSIS OF GROWTH RECORDS ON MALEIC HYDRAZIDE TRIAL

1954 Aug.-Jan. n.s.	J ₆ < S ₆ < A ₂ < S ₂ < J ₂ < A ₆ < O 63 135 253 261 302 339 374 5% 1%	J < S < A < O 182 188 196 374 5% n.s.	0.6% < 2% < O 179 272 374 n.s.
1955 Feb.-July 0.1%	J ₆ < S ₆ < J ₂ < S ₂ < A ₆ < O < A ₂ 202 488 812 848 871 1002 1119 1% 0.1%	J < S < A < O 507 668 995 1002 5% n.s.	0.6% < 0.2% < O 520 926 1002 5%
Aug.-Jan. n.s.	J ₆ < A ₆ < S ₆ < J ₂ < A ₂ < S ₂ < O 117 140 301 306 356 540 800 1% 0.1%	J < A < S < O 211 248 420 800 0.1% n.s.	0.6% < 0.1% < O 176 401 800 0.1%
Total	J ₆ < S ₆ < A ₆ < J ₂ < S ₂ < A ₂ < O 319 789 1011 1118 1388 1475 1802 5% 5% 1% 0.1%	J < S < A < O 718 738 1243 1802 5% n.s.	0.6% < 2% < O 706 1327 1802 5%
1956 Feb.-July 1%	J ₆ < A ₆ < S ₆ < A ₂ < J ₂ < S ₂ < O 394 645 824 921 955 1184 1245 5% 1% 0.1%	J < A < S < O 674 783 1004 1215 5% n.s.	0.6% < 0.2% < O 621 1020 1245 5%
Aug.-Jan. n.s.	S ₆ < S ₂ < A ₆ < A ₂ < J ₆ < J ₂ < O 403 446 450 571 578 1073 1223 n.s.	S < A < J < O 424 510 825 1223 n.s.	0.6% < 0.2% < O 477 797 1223 n.s.
Total	J ₆ < A ₆ < S ₆ < A ₂ < S ₂ < J ₂ < O 972 1095 1227 1492 1630 2028 2468 5% 5% 5%	A < S < J < O 1268 1428 1500 1630 n.s.	0.6% < 0.2% < O 1078 1717 2468 1%
1957 Feb.-March 1%	S ₂ < S ₆ < A ₆ < J ₆ < A ₂ < J ₂ < O 65 73 207 227 258 340 502 5% 1% 0.1%	S < A < J < O 69 232 283 502 5% 1%	0.6% < 0.2% < O 169 221 501 1%
Total 0.1%	J ₆ < S ₆ < A ₆ < S ₂ < A ₂ < J ₂ < O 1581 2224 2652 3344 3478 3788 5146 5% 0.1%	J < S < A < O 2684 2759 3065 5146 1%	0.6% < 0.2% < O 2152 3537 5146 1%

Symbols used:

O = Control.

J₂ = 0.2% Maleic Hydrazide applied in July.

J₆ = 0.6% " " " " " "

A₂ = 0.2% " " " " " August.

A₆ = 0.6% " " " " " "

S₂ = 0.2% " " " " " September.

S₆ = 0.6% " " " " " "

The figures beneath the symbols are the total growth in millimetres per 12 branches over the period under review. Statistically significant differences are indicated by the horizontal arrows. The symbols for treatments are arranged in order of growth, those with the least on the left. The overall statistical significance of the treatment effect is given under the figure for the year (n.s. = not significant).

All Maleic Hydrazide treatments have shown with only one exception (a 0.2% spray in August—the February to July period of 1955) consistently lower growth rates than the control in each of the half-yearly periods. Further 0.6% overall has shown less growth than 0.2% which in its turn was less than control for every period analysed. In both years the effect was most with July and least with August spraying. For the total duration of the experiment, July spraying produced the maximum growth reduction and August the least. This was also true for 1954 and 1955, but in 1956 the position was reversed, August spraying producing maximum inhibition and July the least. However, in all three years July spraying at 0.6% produced the maximum inhibition and it was only in the August—January period of 1956 and the February—May period of 1957 that it did not produce maximum inhibition. Over the total period the three 0.6% sprays occupied the first three positions and the 0.2% the last three positions when arranged in order of degree of inhibition. A similar trend is noticeable for each of the individual periods, but there are several exceptions. Considering the seasonal effects, the July application of 0.6% sprays depressed growth most, except during the period August, 1956, to March, 1957. The August application produced more growth than the September spray, from August, 1954, until August, 1955; thereafter it produced less growth until September, 1956, when the September application produced the lowest growth rate of all the 0.6% treatments, until the end of the experiment.

With the 0.2% treatments, the effects of time of application were less marked. From August, 1954, until January, 1955, the August application was the most depressing and July the least. From then until July, 1955, the differences were slight, but August produced the least depression. Then the July application became most depressing, with September least. From October, 1955, differences were small until September, 1956, when the September application exerted a very strong depression, in fact the strongest of all treatments. The July application was the least. These relative changes are obviously due to the timing of the spray application, but generally this is less than expected. This is doubtless due to the extremely long duration of the spray effect, growth depression being operative a year after spraying and thus there was a residual effect when the next spray was applied.

In general the amount of depression of growth appears to be more a function of the spraying date than of the time in the growth cycle it was applied. Further it appears to depend on the year. There also appears to be some interaction with concentration, e.g. although the order for 0.6% and 0.2% sprays in 1955 was July, September, August in both cases, in 1956 it was July, August, September with 0.6% and August, September, July with 0.2%. There is certainly no suggestion of a regular July, August, September sequence as might have been expected.

A point of great importance is that the inhibition is of long duration, persisting throughout the year and not confined to the second half of the growth period. In fact, as can be seen from the data for the February—July period, considerable inhibition of the first flush of growth of the Rains is exhibited by all spraying treatments applied the previous year. It is evident that the aim of the experiment, to produce varying degrees of inhibition of growth for varying periods in the second half of the Rains only, was not obtained.

All treatments were found to have produced growth abnormalities when the trees were inspected on May 13, 1955. The maximum abnormality consisted of complete lack of growth on the primaries. Many auxiliary shoots were developed, usually several per node, and these had long, narrow leaves. Many of the inflorescence buds were elongated and of vegetative appearance, long, narrow bracts being developed on them.

Abnormalities were more noticeable on the 0.6% than the 0.2% treatments and on the July and September sprayings. This is similar to the effects on growth rate. The individual treatments in order of abnormality development were as follows:—

$$J_6 > S_6 > A_6 > S_2 > J_2 > A_2$$

The 0.2% August spray thus produced least abnormality, only a few elongated leaves on one tree of those examined being noticed.

In an examination on March 22, 1956, similar abnormalities were again reported.

During the visit of May 13 the heads were found to be approaching the end of the cycle and a count of the number of suckers on each of the first five trees in each plot was made. The results were as follows:—

$$\begin{array}{cccccccccccccccc} S_2 < O < A_2 < J_6 < A_6 < J_2 < S_6 : O < A < S < J : O < 0.2\% < 0.6\% \\ 42 & 51 & 53 & 66 & 72 & 74 & 86 : 51 & 62 & 64 & 70 : 51 & 56 & 75 \end{array}$$

Although the differences did not reach significance, it is interesting to note that the main treatment effects were in the same order as for growth and it may be inferred that the sprays had increased the degree of sucker development.

Effects on Flowering

The effects on flowering scores were as follows:—

20/2/55.

$$\begin{array}{ccccccc} S_6 < J_6 = J_2 < A_6 < S_2 < A_2 < O \\ 21 & 34 & 34 & 36 & 40 & 47 & 55 \\ \xleftarrow{5\%} & & \xleftarrow{5\%} & & \xleftarrow{1\%} & & \end{array}$$

$$\begin{array}{cccc} S < J < A < O \\ 30 & 34 & 41 & 55 \\ \xleftarrow{5\%} & & \xleftarrow{5\%} & \\ \xleftarrow{1\%} & & \xleftarrow{1\%} & \\ \xleftarrow{0.1\%} & & & \end{array}$$

$$\begin{array}{ccc} 0.6\% < 0.2\% < O \\ 30 & 40 & 55 \\ \xleftarrow{5\%} & & \end{array}$$

25/4/55.

$$\begin{array}{ccccccc} J_6 < J_2 < S_6 < A_2 < O < A_6 \\ 53 & 68 & 73 & 81 & 85 & 107 \\ \xleftarrow{5\%} & & \xleftarrow{5\%} & & \xleftarrow{1\%} & & \end{array}$$

$$\begin{array}{cccc} J < S < O < A \\ 60 & 78 & 85 & 94 \\ \xleftarrow{5\%} & & \xleftarrow{1\%} & \end{array}$$

$$\begin{array}{ccc} 0.6\% = 0.2\% < O \\ 78 & 78 & 85 \\ \text{n.s.} & & \end{array}$$

Total 1955.

$$\begin{array}{ccccccc} J_6 < S_6 < J_2 < S_2 < A_2 < O < A_6 \\ 77 & 94 & 102 & 124 & 128 & 140 & 143 \\ \xleftarrow{5\%} & & \xleftarrow{5\%} & & \xleftarrow{1\%} & & \end{array}$$

$$\begin{array}{cccc} J < S < A < O \\ 89 & 109 & 135 & 140 \\ \xleftarrow{5\%} & & \xleftarrow{1\%} & \\ \xleftarrow{0.1\%} & & & \end{array}$$

$$\begin{array}{ccc} 0.6\% < 0.2\% < O \\ 118 & 125 & 140 \\ \xleftarrow{1\%} & & \xleftarrow{5\%} \end{array}$$

12/4/56.

$$\begin{array}{ccccccc} 1\% J_6 < S_6 < J_2 < A_6 < O < A_2 \\ 48 & 76 & 78 & 90 & 94 & 97 \\ \xleftarrow{1\%} & & \xleftarrow{5\%} & & \xleftarrow{0.1\%} & & \end{array}$$

$$\begin{array}{cccc} J < S < A < O \\ 63 & 84 & 93 & 94 \\ \xleftarrow{1\%} & & & \end{array}$$

$$\begin{array}{ccc} 0.6\% < 0.2\% < O \\ 71 & 89 & 94 \\ \xleftarrow{1\%} & & \end{array}$$

The tendency was for Maleic Hydrazide spraying to cause a reduction in flowering. The 0.6% sprays tended to produce a bigger reduction than the 0.2% sprays. In the later flowering of 1955 and in that of 1956, the July spray reduced flowering to the greatest extent, the August spray to the least extent. These results and those of growth in the preceding periods are similar. The 0.6% July spraying was most depressive in both cases. It may be inferred that the flowering was reduced because the amount of mature wood and foliage had been reduced by spraying.

Effects on Yield

The results of the various measurements employed are summarized in Table LXIX.

The effects of the spraying treatments on cherry yield have been very slight, none of the overall treatment effects reaching statistical significance in any of the years. There appears to be a marked trend for the 0.6% July spray to produce the lowest yield. There is also a trend for 0.6% sprays to produce lower yields than the 0.2%.

Differences between treatments are more clearly shown up by the clean coffee yields, but even so, only in one year (1955-56) did the overall treatment differences reach significance. The pattern of the treatment effects was similar to that for cherry yields. The 0.6% July spray produced consistently the lowest yield in each year, the difference between this and that of the next lowest yielding

TABLE LXIX. RESULTS OF STATISTICAL ANALYSIS OF YIELD DATA, MALEIC HYDRAZIDE TRIAL
For symbols and methods of presentation see Table II

For symbols and methods of presentation see Table II									
Cherry Weights cwt./acre.									
1954-55	$J_2 < J_6 < O < S_6 < S_2 < A_6 < A_2$	23.59	24.91	26.73	29.47	29.90	30.41	33.07	$J < O < S < A$
n.s.									24.25 26.73 39.04 31.74
									n.s.
1955-56	$J_2 < J_6 < S_6 < A_2 < S_2 < O < A_6$	18.28	18.62	19.00	21.74	23.70	25.01	25.34	$J < S < A < O$
Nearly 5%									18.45 21.10 23.54 25.01
									←5%→
1956-57	$J_6 < J_2 < A_6 < S_6 < O < A_2 < S_2$	17.18	24.15	24.97	25.22	25.68	26.44	29.90	$J < O < A < S$
n.s.									20.66 25.68 25.70 27.56
									←5%→
Three-year total.	$J_6 < J_2 < S_6 < O < A_6 < A_2 < S_2$	20.24	20.00	24.30	25.81	26.91	27.28	27.51	$J < O < S < A$
n.s.									21.12 25.81 25.90 27.09
									←5%→
Clean Coffee cwt./acre									
1954-55	$J_6 < J_2 < S_6 < O < A_2 < S_2 < A_6$	2.72	3.72	4.47	4.52	4.69	4.76	4.94	$J < O < S < A$
n.s.									3.22 4.52 4.61 4.81
									←5%→
1955-56	$J_6 < J_2 < S_6 < S_2 < A_2 < A_6 < O$	1.87	2.53	2.87	3.00	3.18	3.53	3.53	$J < S < A < O$
5%									2.21 2.94 3.36 3.53
									←5%→
									←1%→
1956/57	$J_6 < A_2 < A_6 < S_6 < O < J_2 < S_2$	1.94	2.90	3.00	3.18	3.19	3.59	3.72	$J < A < O < S$
n.s.									2.76 2.95 3.19 3.45
									n.s.
Three-year total	$J_6 < J_2 < S_6 < A_2 < O < A_6 < S_2$	2.18	3.29	3.51	3.59	3.74	3.82	7.41	$J < S < A < O$
Nearly 5%									3.71 3.67 3.71 3.74
									←5%→
									←1%→
A + B size. cwt./acre									
1954-55	$J_6 < J_2 < S_6 < A_2 < O < S_6 < A_6$	0.195	0.380	0.400	0.500	0.509	0.547	0.607	$J < S < O < A$
Nearly 5%									0.193 0.474 0.509 0.551
									←5%→
									←1%→
1955-56	$J_6 < S_6 < J_2 < S_2 < A_2 < O < A_6$	0.066	0.100	0.115	0.129	0.133	0.158	0.165	$J < S < A < O$
5%									0.090 0.121 0.149 0.158
									←5%→
									←1%→

1956-57 n.s.	$J_6 < A_6 < A_7 < J_2 < S_6 < S_2 < O$ 0.619 0.972 0.978 1.054 1.091 1.221 1.235 ←5%→	$J < A < S < O$ 0.837 0.975 1.156 1.235 n.s.	0.6 % 0.894	0.2 % 1.085 n.s.	O 1.235
Three-year total n.s.	$J_6 < J_2 < S_6 < A_2 < S_2 < A_6 < O$ 0.488 0.857 0.921 0.930 0.965 1.071 1.102 ←5%→1%→	$J < S < A < O$ 0.673 0.943 1.000 1.102 ←5%→1%→	0.6 % 0.827	0.2 % 0.917 5%→	O 1.102
A + B size as per cent of Clean Coffee					
1954-55 n.s.	$J_6 < S_2 < A_2 < J_2 < S_6 < A_6 < O$ 6.30 8.28 9.91 10.07 10.23 10.95 12.17 ←5%→	$J < S < A < O$ 8.18 9.26 10.44 12.17 ←5%→	0.6 % 9.16	0.2 % 9.42 5%→	O 12.17
1955-56 n.s.	$J_6 < S_6 < S_2 < A_2 < O < J_2 < A_6 < O$ 28.53 34.50 37.29 37.43 39.76 39.87 40.88 ←5%→	$J < S < A < O$ 34.20 35.89 39.16 39.76 n.s.	0.6 % 34.64	0.2 % 38.20 n.s.	O 39.76
1956-57 n.s.	$J_6 < S_6 < A_6 < S_2 < A_2 < J_2 < O$ 26.11 26.21 26.92 27.60 28.31 30.97 32.71 n.s.	$S < A < J < O$ 26.90 27.61 28.54 32.71 n.s.	0.6 % 26.41	0.2 % 28.13 n.s.	O 32.71
Three-year total n.s.	$J_6 < S_6 < S_2 < A_2 < A_6 < J_2 < O$ 20.31 23.65 24.39 25.22 26.25 26.97 28.21 n.s.	$J < S < A < O$ 23.64 24.02 25.73 28.21 n.s.	0.6 % 23.40	0.2 % 25.52 n.s.	O 28.21
500 Bean Weight in grams					
1954-55 1 %	$J_6 < A_2 < S_2 < S_6 < J_2 < A_6 < O$ 47.00 51.40 51.65 51.74 51.99 52.14 52.67 ←1%→0.1%→	$J < S < A < O$ 49.49 51.70 51.77 52.67 ←5%→1%→	0.6 % 50.28	0.2 % 51.48 1%→	O 52.67
1955-56 5 %	$J_2 < J_2 < A_6 < A_2 < S_6 < O < S_2$ 58.12 63.55 63.71 64.51 64.91 66.05 66.34 ←5%→1%→0.1%→	$J < S < A < O$ 60.83 64.11 65.63 66.05 ←5%→1%→0.1%→	0.6 % 62.20	0.2 % 64.80 5%→	O 66.05
1956-57 n.s.	$J_6 < O < J_2 < A_2 < A_6 < S_2 < S_6$ 61.17 62.61 62.64 63.03 63.84 64.07 64.95 n.s.	$J < O < A < S$ 62.16 62.64 63.43 64.51 n.s.	O 62.64	0.2 % 63.25 n.s.	O 64.51
Three-year total 1 %	$J_6 < J_2 < A_2 < A_6 < S_6 < O < S_2$ 55.60 59.40 59.65 59.94 60.37 60.44 60.85 ←1%→0.1%→	$J < A < O < S$ 57.49 59.50 60.44 60.61 ←1%→0.1%→	0.6 % 58.64	0.2 % 59.97 5%→	O 60.44

treatment usually being marked and much more so than the differences between the rest of the treatments. The difference between the yield of the 0.6% July spray and those of most of the other treatments was usually statistically significant, but this should be regarded with caution except in 1955-56, owing to lack of overall significance between treatments. There were also significant differences between the July treatments as a whole and some or all of the other treatments. The 0.6% sprays produced consistently the lowest yields but only significantly so in 1955-1956 and then only in comparison with control. Over the three years the overall treatment differences did not reach significance.

The yield of A+B grade beans gave rather similar results to those outlined above. The A+B expressed as a percentage of clean coffee again gave similar trends, but overall significant differences due to treatment were not attained in any year.

The 500 bean weight was found to be a particularly sensitive measure of treatment effects. In both 1954-1955 and 1955-1956 and also the three-year total, the overall treatment effects reached significance. Only in 1956-1957 was there no significant difference. The 0.6% July spray produced a significantly lower yield than any other treatment, similarly the sum of the July spray treatments (note, however, that in 1954-1955 the 0.2% July spray produced a relatively high yield). The 0.6% sprays produced significantly lower yields than the control and, in one case, than the 0.2% spray.

In none of the crop characteristics measured was there a real indication of any increase from any of the treatments, though on occasions improvements over control were evident. The crop reductions are closely paralleled by the effects on growth, flowering and induced abnormality. The evidence is thus against the premise on which the experiment was set up. It is manifest, however, that the treatments did not control growth in the manner desired: contrary to the intention, growth was reduced throughout the year. Consequently yields were depressed, but in view of the effects it is surprising that significant decreases were restricted to the July spraying treatments. Sincere thanks are due to Universal Crop Protection and Fison's Pest Control Ltd. for supplying chemicals and to Mr. C. R. Tofte of "Riverglade Estate" for allowing the experiment to be conducted on his coffee.

PLANT PATHOLOGY

Leaf Rust (*Hemileia vastatrix*)

Investigations on leaf rust have hitherto been confined to general observations on the epidemiology of the disease and its seasonal fluctuations. The incubation period has been thoroughly investigated at Ruiru during the past two years however. From a study of the effect of temperature on incubation period at Ruiru it has been possible to deduce the likely variation in other localities in Kenya. The outstanding result of this investigation was the discovery that the incubation periods are much longer in Kenya than in Ceylon and Southern India, where the classical investigations of the disease were carried out. Thus a minimum of four weeks and a maximum of eight weeks has been found in Kenya whereas 10-14 days was recorded in the literature. This discovery profoundly affects the timing of fungicidal control; combined with observations of epidemiology it has been possible to formulate precise spray schedules for Kenya. The programme devised has still to be tested and proven by field experiments. Moreover, a more precise idea of the conditions under which infection takes place is required and investigations have been started to this end.

Epidemiology of 1956

During 1954 and 1955 there was infective weather in the first three months of the year. This has led to epidemics of increasing severity in the middle of the year. As a result, the level of infection at the beginning of 1956 was appreciable. The occurrence during January and February of heavy rainstorms resulted in infection taking place on several occasions. As predicted at the time, this led to an early build up of rust and a heavy outbreak in August. Severe leaf fall resulted and the consequent reduction in inoculum, together with the lack of infective weather during August and the greater part of September, led to only a relatively mild further attack during the Short Rains. Nevertheless, there was still an appreciable amount of inoculum on the trees at the end of the year.

Rust Race and Coffee Variety Testing

During overseas leave the Plant Pathologist visited the Coffee Rust Research Station at Oeiras, near Lisbon, and studied the methods being used by Dr. B. d'Oliveira to determine the races of *Hemileia vastatrix* and their reactions on coffee varieties. Subsequently similar work was commenced at Ruiru in October. The aim was firstly to clarify the position as regards rust attack on the variety K7, secondly to investigate the occurrence and distribution of rust races in Kenya, thirdly to check on the behaviour of rust races and coffee varieties under Kenya conditions and fourthly to observe and note rust races so far unrecorded by d'Oliveira. The first tests undertaken were designed to determine the race of rust attacking some F3 K7 plants on the Coffee Research Station, and also of some rust occurring on Amphillo. Examination showed that many of the K7 plants with rust were morphologically not true K7 types. The remainder appeared true to type but were attacked by rust. Tests indicated that segregation must have occurred, as the rust could not be made to infect certain F2 K7 clones. In the case of Amphillo, d'Oliveira had found that some plants of this variety react similarly to K7 and are resistant to his race II, the common Kenya rust, but are susceptible to his race I. The rust on the Amphillo plants did not attack K7 and therefore was assumed to be race II, a conclusion later confirmed by d'Oliveira from tests on a duplicate rust collection.

Only two races of rust have so far been found in Kenya: rust II, which is widespread, and rust I isolated by d'Oliveira from K7 plants in the Teita Hills. In a test at Ruiru last year it was found very difficult to get this rust to take on K7.

Studies on factors Influencing Infection

Preliminary investigations were made on the factors influencing infection of coffee leaves by *Hemileia vastatrix* and of the methods which could be used in these studies.

A technique for depositing dry spores on leaves originated at Long Ashton Horticultural Research Station was very satisfactory for work with coffee rust.

After a series of laboratory tests using this technique it was concluded that the majority of spores floating in the air will deposit on the upper-surfaces of leaves and only reach the under-surfaces by rain-washing and splashing up from the surface of underlying leaves. Such splashing of leaf under-surfaces is common during heavy rainstorms. Some adherence to under-surfaces may also occur when these are wet with rain or dew, but certainly during rain there will be relatively low amounts of spores in the air. The main source will be lesions which are caused to liberate spores by the impact of raindrops on the leaves. This mechanism may explain the common observation of a ring of young spores around an old lesion. Alternatively, a raindrop may hit a lesion and shatter into droplets containing spores which will spatter and land on other leaves. The trail of young lesions arranged in a definite direction along the leaf, away from the lesion which is sometimes observed, may be explained by a rain splash running across the lesion.

The normal path by which spores reach the under-surface of the leaf, where they germinate and penetrate the leaf, is via the upper-surface. It is feasible, therefore, that fungicides applied to the upper-surface, if washed off in sufficient strength by rain, can inhibit spore germination by transfer of fungicide in the splash to the lower surface. This may constitute an efficient way of controlling the disease, since it might be easier to achieve a toxic level of fungicide in the splash (from the upper-surface) than to try to spray the under-surface so that an adequate protective cover of fungicide is produced.

This proposition was tested by spraying the upper-surface of coffee leaves with various fungicides, allowing them to dry, then spraying on distilled water and collecting the drippings. Hanging drops were made from these and rust spore germination in them tested. In the first two experiments, six slides from six untreated leaves and six from treated ones were made. In the latter tests comparing two fungicides, four slides were from four untreated leaves and four from each of the two fungicide treatments. The fungicide treatments were 5 lb./100 gallons of water for the "50%" copper proprietary brands and the equivalent concentration of 1% Burgundy mixture.

TABLE LXX

The Germination of Hemileia vastatrix spores in drippings from coffee leaves previously sprayed with various fungicides

(Germination Percentage)

<i>Experiment No.</i>	<i>Unsprayed</i>	<i>Perenox sprayed</i>	<i>Second fungicide used and name</i>
1*	52.3	27.3	—
2a	56.3	17.0	—
b	47.3	18.0	—
3a	88.0	7.0	8.0 Burgundy
b	87.5	8.0	10.0 „
4a**	27.3	17.5	7.3 Cuprokylt.
b	87.0	25.5	18.0 „
5	87.0	23.0	12.5 „
6a	35.2	3.5	23.0 Cupromox
b	88.0	5.5	13.0 „
7	56.5	21.0	20.0 „

a = count on afternoon of same day.

b = count on morning of following day.

* = some rainfall between spraying the fungicide and the collection of washings.

** = Some slides affected by drying out.

TABLE LXXI

Germination of Hemileia vastatrix spores in drippings from coffee leaves previously sprayed with various fungicides expressed as percentage of spores germinating on unsprayed controls

(Germination Percentage)

Experiment No.	Perenox	Second fungicide and name
1	47.6	—
2a b	31.1 28.6	— —
3a b	10.3 7.1	11.8 Burgundy 11.8 „
4a 4b	64.1 92.8	30.8 Cuprokylt 65.4 „
5	26.4	14.4 Cuprokylt
6a b	9.9 8.3	52.8 Cupromox 19.7 „
7	37.4	35.4 Cupromox

In all cases germination was reduced, often very markedly. All the fungicides were effective, with slight relative differences as shown in the foregoing tables.

The tests were "in vitro" germination and further tests should be conducted on living leaves. Although germination was not completely inhibited in any case, the effect on penetration has still to be studied.

The indications are that the effect of fungicide cover on the upper-surface of the leaf should be studied in the field.

Another method evolved at Long Ashton was investigated, namely, the use of cellulose acetate film casts of leaf surfaces for following germination of rust spores and penetration on living leaves, with the modification that Congo Red was a much better stain than Safranin. The method was found very satisfactory for *Hemileia vastatrix* investigations.

ENTOMOLOGY

General Pest Situation

The year was notable for the activity of Lepidopterous pests. Outbreaks of Leafminer (*Leucoptera* spp.) and Leaf Skeletoniser (*Epiplema dohertyi* Warr.) occurred. Tip Borer, *Eucosma nereidopa* Meyr, did serious damage to growth required for new multiple-stem cycles in Upper Kiambu, where it also attacked the young berries. Another Tip Borer, *Archips occidentalis* Wals., did similar damage to young growth in Thika, but recovery was satisfactory owing to the more rapid growth of the coffee in this area.

Antestia, *Antestiopsis lineaticollis* Stal, caused trouble on estates which had neglected routine testing and control measures. In a serious outbreak in Ruiru an average population of 250-300 *Antestia* per tree was found.

Research on Insect Pests of Coffee

1. *Antestia*, *Antestiopsis lineaticollis* (Stal).

(a) *Airspraying*. In an experiment to assess the effectiveness of aircraft spraying, the following treatments were used:—

- (1) 3 pints D.D.T. 25 per cent emulsion concentrate per acre.
- (2) 2 pints D.D.T. 25 per cent emulsion concentrate + 3 fl. oz. of an emulsifiable concentrate of pyrethrum containing 5 per cent pyrethrins and 50 per cent piperonyl butoxide per acre.

Treatment 1 reduced the *Antestia* population from 67.3 per tree to 19.4 per tree. Treatment 2 gave a reduction from an average of 21.6 *Antestia* per tree to 4.6 per tree. As neither treatment gave the necessary reduction to an average of under 2 per tree, results were not considered satisfactory. No other opportunity occurred during the year to pursue this work.

(b) *Sprays against Antestia*. A number of insecticides were tested in a series of experiments against *Antestia* towards the end of the year. Of these, Chlorthion and Malathion showed promise. As Malathion was locally available work was pressed forward with this insecticide, but recommendations on its use could not be made before the end of the year.

Review of Research on *Antestia*.

The first real progress in control of *Antestia* was made in the early 1930s, when sodium arsenite bait spraying (1), in itself not a particularly effective measure, was superseded by spraying with kerosene extract of pyrethrum (2). Further improvement was achieved by dusting with pyrethrum powder (3) in 1935. From this time onward, few improved control measures were devised, although BHC was found effective (4) and was for a time recommended. This material was, however, found to impart an undesirable flavour to coffee (5) and recommendations for its use were withdrawn. D.D.T. was only recommended for use on serious infestations and pyrethrum powder continued to be recommended. Towards the end of 1956 malathion was demonstrated to be effective, as reported above.

2. *Leafminers*, *Leucoptera* spp.

Serious outbreaks of both species of Leafminer occurred in the Central Province in the latter half of the year.

A number of insecticides were tested against Leafminer larvae in the leaves and of these Diazinon was the most efficient. This insecticide regularly gave kills of 90-100 per cent of the larvae within the leaves. As an interim recommendation, the use of Diazinon 60 per cent emulsifiable concentrate applied to the foliage at a concentration of half-pint of the concentrate in 40 gallons of water was advised. A single application did not always give complete control, but further work on spray timing could not be done before the outbreaks ceased.

Most attacks of Leafminer were due to natural parasite failures and did not invariably follow foliage sprays of persistent insecticides, although this was thought to have happened on some estates.

Review of Research on Leafminers.

No insecticidal control of these insects had been achieved in Kenya until Diazinon was tested against them (6) and was found to be effective against the larvae in their mines. In other parts of the world, closely related insects had been controlled with parathion or B.H.C. dusts. As, however, parathion is highly toxic to man and as B.H.C. imparts "bricky flavour" to coffee, neither of these lines were pursued in Kenya, search for control measures being directed towards achieving control with less toxic materials and with materials unlikely to produce taints.

3. *Leaf Skeletonizers, Epiplema dohertyi* Warr. and *Odites artigena* Meyr.

The former insect caused damage from June until the end of the year on some estates in Ruiru. Control of the larvae was achieved by dusting with a 5 per cent D.D.T. dust at a rate of 30 lb. per acre, or by dusting with a synergised pyrethrum dust containing 0.2 per cent pyrethrins and 2 per cent piperonyl butoxide at a rate of 10-12 lb. per acre. The latter insect was noticed on an estate in Thika, but the attack was not serious and no control measures were required.

Review of Research on Leaf Skeletonizers.

As these insects are minor pests of coffee, little attention has been paid to them. Apart from records of their occurrence (8 and 9) there is little account of them. Being leaf-eating insects, control with lead arsenate is not difficult.

4. *Tip Borers, Eucosma nereidopa* Meyr. and *Archips occidentalis* (Wals.).

(a) *Eucosma nereidopa* Meyr. This insect did most damage in Upper Kiambu and the Teita Hills, but was also found on coffee in areas west of the Rift Valley.

No satisfactory control of this insect was achieved but information on parasites attacking its larvae and on its biology was obtained.

(b) *Archips occidentalis* (Wals.) Control of the larvae of this moth was achieved by sprays of 0.1 per cent D.D.T. on the tips and apical foliage of young vertical growth. The larvae do not confine their activities exclusively to boring in the tips, and feed to some extent on the foliage. Control was therefore not so difficult as with *E. nereidopa*, whose larvae do not leave their tunnels until they have ceased to feed.

Review of Research on Tip Borers.

E. nereidopa was first recorded attacking coffee in Kenya in 1932 (10) and further work was done on its distribution in Uganda in 1946-48 (11). It was already known to be a serious pest of coffee in the Teita Hills (12).

Archips occidentalis (Wals.) has long been known as the Tip Borer of coffee at lower altitudes, but is not usually a pest of importance.

5. *Fruit Fly, Ceratitis capitata* Wied.

This insect caused a certain amount of fall of green berries in the early part of the year. The berry fall was caused by the flies ovipositing but the larvae failed to mature in this material. The damage was fleeting but alarming at the time. No control measures could be taken before the damage was noticed.

Review of Research on Fruit Fly.

The Mediterranean Fruit Fly is a pest of importance on many fruit crops and much investigation has been pursued on it. In coffee, however, it is not a pest of importance as only ripe cherry is usually attacked, the larvae being unable to penetrate the bean due to the hardness of the parchment at this stage (13). The previous record of its attacking green berries was in 1934 (14).

6. *White Borer, Anthores leuconotus* Pasc.

A campaign against White Borer was carried out in the Makuyu, Mitubiri and Donyo Sabuk areas during the first three months of the year. Growers were given the option of controlling the pest by either fumigation or spraybanding the trees with $\frac{1}{2}$ per cent Dieldrin.

Field experimentation to determine the efficiency of Dieldrin spraybanding was continued. The results were much better than those obtained by fumigation of the larvae, and growers were accordingly advised to use Dieldrin to the exclusion of other methods.

Review of Research on White Borer.

White Borer is a serious pest of coffee at altitudes below about 5,000 ft. throughout East and Central Africa. Investigations in Kenya (15) determined the life-history and indigenous plant hosts of the insect. The control advised was the extraction of the larvae with pieces of wire from their burrows. Fumigation of the larvae was advised from 1949 (16). Real advance in control measures was, however, made in Tanganyika when control was achieved by the use of $\frac{1}{2}$ per cent. Dieldrin spraybands applied to the lower 18 in. of the trunks of the trees (17).

7. Coffee Lacebug, Habrochila ghesquierei Schout.

Lacebug was found for the first time in the Central Province on coffee in Kabete. The damage done was usually of a minor nature, but sprays of Diazinon 60 per cent emulsion concentrate gave good control of it at a concentration of half a pint of Diazinon in 40 gallons of water. Two sprays separated by a period of three weeks were necessary as the eggs of the insect were not killed by the insecticide. The Mirid predator, *Stethacomus* sp., was found in association with the Lacebug in Kabete.

Review of Research on Lacebug.

Lacebug is a minor pest of coffee and little attention has been paid to it in Kenya until 1952, when outbreaks occurred following D.D.T. sprays (18). Control of Lacebug was to some extent achieved with nicotine/soap sprays (19).

Miscellaneous Items

The compilation of a list of the insects associated with coffee in Kenya occupied some time. This list was for incorporation into a comprehensive list of all recorded insect pests of agriculture in the East African Territories.

The collection of insects associated with coffee also received attention and is now fairly comprehensive. The assistance rendered by the Commonwealth Institute of Entomology in the identification of many insects is gratefully acknowledged.

The Senior Entomologist, Dr. R. H. Le Pelley, assumed technical supervision of coffee entomology from July.

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COFFEE BERRY DISEASE RESEARCH

Contributed by Dr. F. J. Nutman, Senior Principal Scientific Officer i/c Coffee Berry Disease Research Unit

The work of the Coffee Berry Disease Research Unit started in May, 1955, at the Coffee Research Station at Jacaranda with the arrival of Mr. K. R. Bock. During the following six months he carried out field trials and a preliminary laboratory study (*E. Afr. agric. J.* Vol. XXII, No. 2, Oct., 1956). In November, 1955, Dr. M. Roberts and Dr. J. Nutman arrived. Limited laboratory accommodation was obtained by January, 1956, by the courtesy of the Director of the E.A. Tsetse Research Organization, but full accommodation was not available until May, 1956. Laboratory equipment arrived in May and in June, 1956.

Field Experiments.

The carrying out of the field experiments has been undertaken by Mr. Bock, with the assistance of Mr. I. Levisur.

The 1955 field trials had shown that an organo-mercurial compound (phenyl mercuric acetate) gave some indication of possible control of coffee berry disease; tests of this fungicide, therefore, were the main object of the 1956 programme.

After a survey of the affected areas both East and West of the Rift, five sites were selected for field trials; these were two estates in Upper Kiambu, one in North Lumbwa, one in the Nandi Hills and one in Cherangani. The experimental design, a 2⁵ confounded block trial, was the same at all sites. It was intended to spray five times during the season, starting with a pre-blossom treatment. Work began, however, too late for a true pre-blossom application to be made, while the number of applications was eventually increased to seven. Other trials, designed to compare the persistence of two fungicides and the effect of varying frequency of treatment, were sited on two Upper Kiambu estates, and other experiments in the form of randomized block trials were carried out at three sites west of the Rift. One of these was designed to test four proprietary fungicides thought to be of possible value on the basis of laboratory studies. The Nandi Hills experiments were later extended to Kapsabet where, with the co-operation of the District Agricultural Officer, treatments with phenyl mercuric acetate were superimposed on an existing varietal trial. In June work was extended to the Nyeri district, where randomized block trials were laid out to study the effect of treatments on mid-season and ripe cherry infection.

Results are, as yet, incomplete but there are indications that an eventual economic control may be possible with organo-mercurial compounds, and also that the treatments before and after flowering are of great importance. In this connection the abnormal flowering experienced over the coffee-growing areas on Kenya during the year has added greatly to the difficulties of the work and, to some extent, to the assessment of the results.

Laboratory and Field studies of the pathogen.

This phase of the work has been undertaken by Dr. Roberts and Dr. Nutman.

Following a general study of the disease in the field and of the fungus in the laboratory, attention has been concentrated on the following main lines of investigation:—

1. A technique for the laboratory assessment for the efficiency of various fungicides: this screening method is now available as a routine check on any new chemical before it is tested under field conditions; saving of time can thus be effected since a preliminary evaluation of a new fungicide cannot be made in the field under less than one crop season.
2. An investigation of the importance of *Colletotrichum coffeanum* as a pathogen of the flowers showed that in some instances losses of up to 90% could occur, while an average value for flower losses in lightly affected plantations was around 15%. Largely as a result of this, emphasis in the spraying programme has been placed on early application, a decision which has been justified by field results. Field observations confirm laboratory work on the importance of this phase of the disease

as this comprises not only flower losses, but the subsequent infection and destruction of the very earliest stages of the developing fruit.

3. A field study of the pathogen indicated that the "overwintering" stage occurs in the tissues external to the developing phellogen and, in particular, in the stipular bracts at the leaf bases. On both stem and bract the fungus can spore freely under suitable conditions, and it can also directly invade the developing crop from either, thus initiating fresh outbreaks.

4. The pathogen can, under certain conditions, invade twigs before phellogen formation occurs, and it can also, sometimes, penetrate the phellogen: in these cases it can penetrate deeply into the tissues, producing a dieback identical with that described as "Elgon dieback". In the laboratory symptoms of Elgon dieback can readily be reproduced by inoculation with spores from berries infected with Coffee Berry disease; further, the fungus isolated from all cases so far examined of natural Elgon dieback can cause typical Coffee Berry disease symptoms when reinoculated on berries.

5. A detailed investigation is in progress of the conditions under which the pathogen can cause infection. The object of this is two-fold: firstly, more detailed knowledge should enable applications of fungicide to be made at times when they are most likely to be effective; secondly, it is hoped to determine by such means whether there are any climatic limits within which the disease may be expected to present, sooner or later, a serious problem, and outside which less serious, or comparatively infrequent, losses can be anticipated. Some progress has been made with this investigation. The temperature relations of growth, spore production, germination, and infection have been determined. The temperature range is fairly narrow, the extreme limits being 62° and 79° F. with a sharply defined optimum at 72° F. (22°C.). Germination and penetration of the berry can be remarkably rapid, there being appreciable germination in as little as 2½ hours under optimum conditions. The relation between germination and actual infection is still being studied, but there are indications that penetration can occur in as little as three hours. The spores of the pathogen are very readily killed by desiccation, the germinating capacity on the surface of berries being reduced by more than 70% after four hours' exposure in the laboratory. On the other hand, a small proportion of the spores can apparently survive unfavourable conditions of humidity for as long as 30 hours and can cause limited infection. Another point of interest is that spores from the lesions on ripe berries (the so-called "brown blight" stage) have a greater germination capacity and are more infective than are those from green berries. The significance of this is that the most likely common means of spread of the fungus is carriage on the persons of workers in the plantation, and, during picking, spores from ripe berries are the ones most likely to be transported in this manner.

6. Field observations have made it clear that, in the main centres of infection, the disease has increased both in range and intensity and heavy losses of crop are being experienced. As an example, one recent sample from an Upper Kiambu plantation showed a 40% infection of young green berries, while plantations hitherto free, or only mildly infected, are now being attacked. Similarly, some serious outbreaks have occurred in one African Land Unit, where the disease has been observed causing appreciable loss at an altitude of 5,200 feet.

RESEARCH ON COFFEE PROCESSING

Mr. J. F. McCloy, Senior Scientific Officer, joined the East African Industrial Research Organization in April, succeeding Mr. D. A. B. Llewelyn, and continued investigations into the problem of artificial drying of parchment coffee. In June Mr. J. S. Grant was seconded to assist with field studies on estates. Although a complete solution is not in sight a great deal of useful work on this intractable problem was completed during the year.

The following summary of conclusions derived from experiments carried out in the 1956-57 coffee season was contributed by Mr. McCloy:—

1. Fifty-eight tests on two bed dryers at any drying air temperature between 100° and 160°F. have shown that:—
 - (a) When drying fully wet coffee to the final dry state without resting period, severe damage (involving the loss of up to three classes) is caused;
 - (b) When drying fully wet coffee to the black stage, damage of up to one class is caused;
 - (c) When drying fully wet coffee to the skin-dry stage, slight damage of about half a class is caused;
 - (d) Somewhat less damage is caused than the above when starting with skin-dry coffee.
2. Sixteen tests show that black stage coffee can be finished in about a week using either radial-flow or floor-ventilated silos, but that an additional loss of about half a class may be caused.
3. Four storage experiments show that coffee machine-dried to the hard black stage can be held for about one month in bags with possibly slight damage. Coffee wetter than the hard black stage is liable to mould growth.
4. Laboratory tests indicate that if coffee is sun-dried to the black stage it can be finished in a dryer using 120°F. air temperature or below without damage.
5. Coffee showing a tendency towards off-flavours may be more severely damaged by machine-drying than coffee of sound quality.
6. Experiments to show if sunlight plays any part in the production of high-quality coffee yielded inconclusive results.

COFFEE SEED

Sources

Coffee seed is collected from the original parent tree of each variety or from plots planted at the Coffee Research Station or sub-stations with clonal material taken from the original tree.

Preparation of Seed

"Cherry is picked in the normal way when ripe and pulped in a hand pulper to avoid damage to the parchment. Light beans are floated off and the heavy beans are transferred to drying trays to drain off excess water. Sieved wood ash or ground charcoal is then mixed with the seed and, by adhering to the mucilaginous layer around the bean it forms a coating which prevents hardening and splitting of the parchment. Seed is then dried in the shade to a moisture content of 15 to 18 per cent. When dry all damaged and malformed beans, elephants and pea berries should be eliminated by hand picking." (Jones, 1953.)

Distribution

Although seed orders are received throughout the year it is only possible to issue seed during and immediately after the picking season as it has been found that the seed may lose its viability by five months from picking. Work is being carried out to determine if the viability may be retained longer by modifying the storage conditions.

The quantities of seed distributed since 1947 are shown in Table LXXII, and Figure IX shows the increasing importance of seed issues to African Areas since 1950. During this period the increase in acreage of African-grown coffee has followed closely the quantity of seed issued by the Coffee Research Services, but the seed issued to European estates appears to have been used for the most part to fill in gaps in existing plantations since the acreage of European grown coffee has increased only slightly.

TABLE LXXII
SUMMARY OF COFFEE SEED ISSUED FROM THE COFFEE SERVICES SOURCES
1947-1956 (All weights in lb.)

Variety/Selection	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	10-year totals
SL.28 . . .	56	36	63	1,456	304	261	480	1,330	1,516	1,956	7,458
SL.34 . . .	35	6	9	37	24	10	324	872	812	1,587	3,716
Blue Mountain	—	—	—	15	310	238	506	743	645	514	2,971
K.7 . . .	—	—	—	1	24	15	40	255	386	294	1,015
SL.14 . . .	—	—	5	29	9	4	390	193	104	156	890
DR.I . . .	28	155	18	26	83	45	237	95	45	—	732
DR.II . . .	21	75	4	42	15	95	242	62	—	—	556
Ke.20 . . .	—	—	—	—	12	54	101	118	167	72	524
Kenya Selected	47	56	41	22	96	12	63	94	37	31	499
SL.9 . . .	—	25	—	8	30	—	101	165	90	—	419
TDR. . . .	—	—	—	—	20	80	56	95	—	—	251
Annual Totals	187	353	140	1,636	927	814	2,540	4,022	3,802	4,610	19,031
Miscellaneous .											392
Grand Total .											19,423

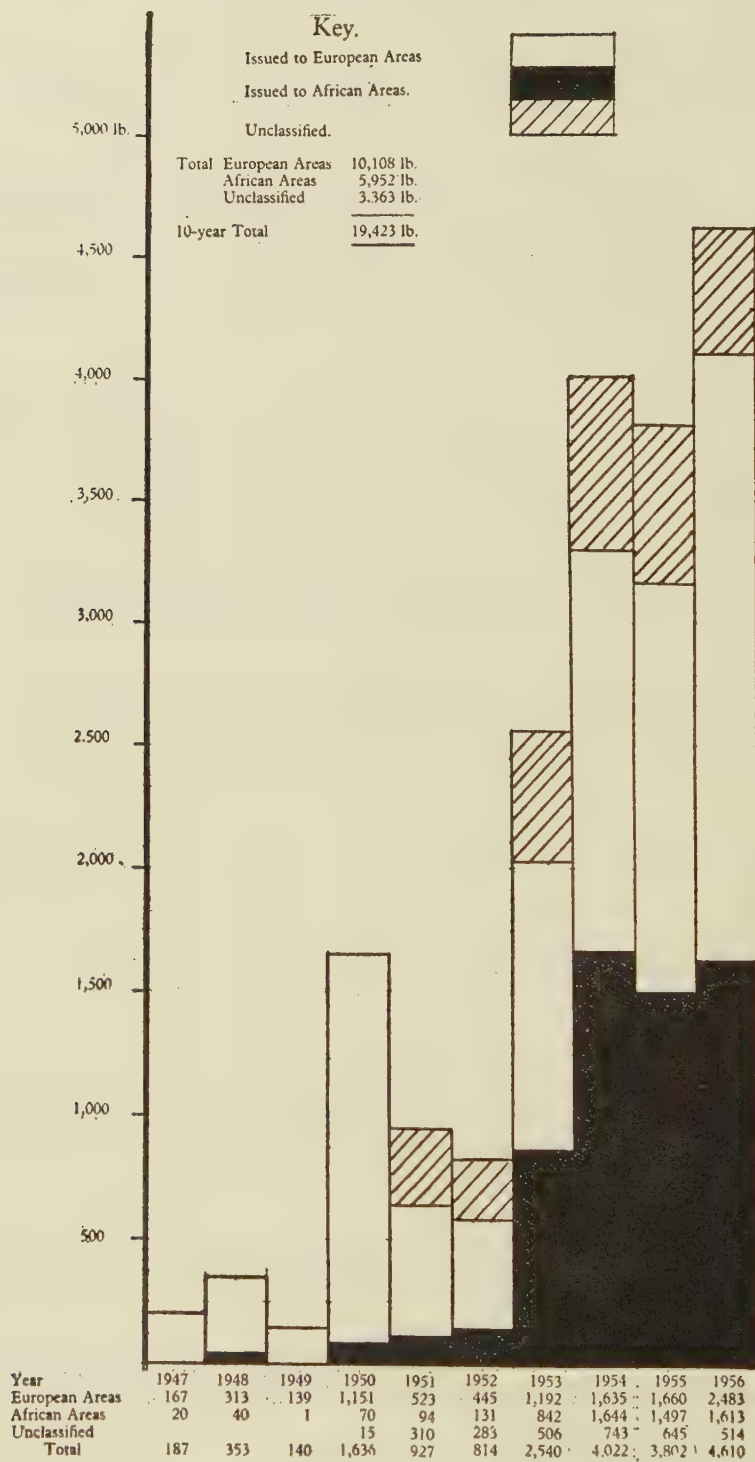
Notes on the sources and characteristics of the varieties and selections mentioned in this section have been published recently. (Jones, 1956.)

References

- JONES, P. A., The management of coffee nurseries in Kenya, *Bull. Coff. Bd. Kenya*, 1953, **18**, 566.
 ———, Notes on varieties of *Coffea arabica* in Kenya, *Bull. Coff. Bd. Kenya*, 1956, **21**, 305.

Fig. IX

COFFEE SEED ISSUES FROM THE COFFEE SERVICES 1947-1956



JACARANDA & RUKERA ESTATE



KEY

- Coffee.
- Napier Grass.
- Ley grazing.

Note : Residual land is rough grazing.

500 0 500 1000 1500

